SECTION 501
PORTLAND CEMENT CONCRETE PAVEMENT

501.01 DESCRIPTION

This work is the construction of portland cement concrete pavement on a prepared subgrade or base course.

501.02 MATERIALS

501.02.1 Concrete

Furnish concrete meeting Section 551 requirements for Class "AP" or "DP" concrete.

A. **Cement.** Furnish Type I or II portland cement meeting ASTM 150 or AASHTO M 85 requirements and the applicable requirements of Subsection 551.02.1.
B. **Air-entraining Admixtures.** Furnish air-entraining admixtures meeting Subsection 551.02.2 requirements.
C. **Fine Aggregates.** Furnish fine aggregate meeting Subsection 701.01.1 requirements.
D. **Coarse Aggregates.** Furnish coarse aggregate meeting Subsection 701.01.2 requirements.
E. **Water.** Furnish water for concrete meeting Subsection 713.01 requirements.

501.02.2 Reinforcing Steel

Steel-wire fabric and steel bar mat sizes and dimensions are specified in the contract.

Furnish steel-wire fabric reinforcement in flat sheets.

Furnish bar mats and bars of structural or intermediate grade, as specified in the contract.

Furnish all reinforcing steel meeting Subsection 711.01 requirements.

501.02.3 Dowel Bars and Sleeves

Furnish Grade 40 plain round dowel bars meeting AASHTO M 31 requirements.

Bar dimensions and placement in the pavement are specified in the contract.

Do not use bars having burrs or other deformation that restrict slipping in the concrete.

Before delivery to the project, coat one-half the length of each dowel bar with one coat of zinc or tar paint. Furnish sleeves for dowel bars meeting the contract requirements.

501.02.4 Tie Bars

Furnish ASTM A 615, Grade 40 deformed steel bars. The length, size, and spacing of the bars are specified in the contract.

501.02.5 Expansion Joint Filler and Joint Sealing Material

Furnish expansion joint filler and joint sealing material meeting Subsection 707.01 requirements.

501.02.6 Curing Compound

Furnish AASHTO M 148 Type 2, white-pigmented, membrane-forming curing compound.

501.03 CONSTRUCTION REQUIREMENTS

501.03.1 Equipment

A. **General.** Do not begin paving operations until all equipment and tools for the pavement construction are available at the site.

Assure the equipment is in good mechanical condition, adjustment, design, and capacity.

Adjust, repair, or replace equipment failing to produce the specified work.

Use handling, batching, mixing, and concrete transporting equipment meeting the applicable requirements of Section 551 and the following.

Use batch plants for projects having 300 cubic yards (229.5 cubic meters) or more portland cement concrete pavement that proportion aggregates and cement by weight using automatic and interlocked proportioning devices.

Use non-agitating hauling equipment with smooth, mortar-tight metal bodies that completely discharge the concrete at a uniform rate without segregation. Provide covers when necessary to prevent the concrete from drying out or being exposed to weather-related moisture.

Use belly-dump trucks only with the Project Manager's written approval.

Remove and dispose of concrete remaining in haul units before reloading with fresh concrete.

B. Stationary Side Forms. Use metal side forms strong enough to resist displacement from concrete and mechanical equipment pressures.

Use flexible or curved forms for curves with 100-foot (30.5 m) radii or less.

Forms must:

1. Hold abutting sections in alignment;
2. Be adjustable for vertical and horizontal curvature;
3. Have a minimum depth equal to the specified concrete edge thickness;
4. Not have horizontal joints;
5. Have a base width greater than or equal to the depth;
6. Have at least three staking points for each 10 feet (3 m) of length that securely lock to the form stake; and
7. Have flange braces and staking pockets that extend outward on the base at least two-thirds the height of the form.

Use wooden forms only with the Project Manager's written approval. Include in the request to use wooden forms complete details showing they meet the requirements for steel forms regarding strength, lines, grades, and depth.

Do not use forms in poor condition in the work. Repaired forms must be inspected and approved before use.

C. Placing, Consolidating, and Finishing Equipment. Place, consolidate, and finish concrete meeting the contract requirements.

Operate only rubber-tired equipment on adjacent pavement. Pad crawler units to prevent pavement damage.

Keep the adjacent pavement and form tops clean to provide good contact with tires or crawler units.

1. Slip-form Pavers. Use slip-form pavers having automatic controls for longitudinal and transverse grade from continuous wire control lines.

Maintain the control wire tension, support interval, and sensor operating pressure to prevent control wire deflection in excess of 3/16-inch (5 mm) below supports at mid-span. Immediately stop paving operations when deflection exceeds 3/16-inch (5 mm) and resume once corrected.

Use self-propelled slip-form pavers to place and finish the concrete that are capable of negotiating all grades without external tractive force.

Equip the slip-form paver with an auger or other approved strike-off device to distribute the concrete to a uniform depth ahead of the screed.

Use sliding forms that are laterally rigid to prevent spreading.

Use slip-form pavers that consolidate the plastic concrete by internally vibrating the full paving width and depth. Use transverse vibrating units that do not project outside the specified paving section thickness and are positioned ahead of the screed a minimum distance equal to the pavement thickness. A series of longitudinal vibrating units may be used as an alternate. Vibrators may be the immersed tube type or a series of equally spaced longitudinal vibrating units.

The maximum spacing of each unit in a series of longitudinal units is 24 inches (610 mm) measured center-to-center of the units.

Each vibratory unit must provide at least 7000 vibrations per minute with the amplitude visibly perceptible on the concrete surface within 1 foot (305 mm) of the entire length of the vibrating unit. Equip the paver with a tachometer or other approved device for measuring the actual vibration frequency.

2. **Auxiliary Finishing Equipment.** Use finishing equipment behind the slip-form paver that automatically maintains alignment from an external reference.

   Provide hand floats, edging tools, and other hand-finishing equipment to finish the surface as specified.
3. **Stationary Side Form Method.** Submit details for all equipment proposed for spreading, strike-off, consolidating, screeding, and floating before use.
4. **Roadbed Planers.** Equip the roadbed planer with adjustable steel cutting edges mounted in a rigid frame to trim the roadbed to the specified elevation and crown under all operating conditions. The planer wheels must ride on the forms or adjacent pavement.
5. **Concrete Spreaders.** Use a self-propelled spreader that uniformly spreads the concrete between forms and has an adjustable blade or head for striking off the concrete to the required height and crown.
6. **Vibrators.** Use full-width concrete slab vibrators of the surface pan type or the internal type with immersed tube or multiple spuds.

   The vibrators may be mounted on the spreader, the finishing machine, or on a separate carriage.

   Do not allow the vibrators to come in contact with the joint load transfer devices, the subgrade, or side forms.

   Use vibrators meeting the following:
   - Surface vibrators having a minimum frequency of at least 3,500 impulses per minute.
   - Tube vibrators with a minimum frequency of at least 5,000 impulses per minute.
   - Spud vibrators with a minimum frequency of 7,000 impulses per minute.
   - Hand-operated or machine-mounted spud-type internal vibrators next to forms having a minimum frequency of 3,500 impulses per minute.
7. **Bridge Deck Finishing Machines.** Use transverse-finishing rotating drum bridge deck finishing machines when stationary side forms are allowed.
8. **Mechanical Floats.** Use mechanical floats that produce a surface true to the required crown and smoothness, free from honeycomb or excessive mortar.

   Assure the float makes accurate incremental adjustments to the required crown without interrupting the float operation.

   The mechanical float may be self-propelled or attached to the rear of the transverse finishing machine.

501.03.2 Pre-paving Conference

Attend a pre-paving conference, conducted by the Department, to be held at least 24 hours before paving starts.

The conference topics will include equipment, construction methods, specification requirements, and lines of communication.

The conference must include the foreman, other Contractor personnel that will supervise the concrete paving operations and key Department inspection personnel.

501.03.3 Aggregate Sampling and Testing

Furnish aggregates that meet the gradation requirements, fineness modulus, and deleterious material limits specified in Subsection 701.01. Provide all sampling and testing to meet these requirements during aggregate production.

501.03.4 Aggregate Production

Produce aggregate meeting the applicable requirements of Section 551.

Produce and stockpile at least one-third of the quantity of each size aggregate necessary to produce the plan quantity of portland cement concrete pavement before paving operations begin.

501.03.5 Acceptance of Aggregate

A. Sampling and Testing. The Project Manager will determine when samples are taken and will test the aggregate for acceptance.

Furnish and operate the aggregate sampling devices, witnessed by the Project Manager. Take samples at a point immediately before the aggregates are combined and enter the mixer, witnessed by the Project Manager. Samples may be split to a minimum 50 pounds (23 kg). Furnish the samples to the Project Manager immediately after sampling.

Acceptance samples will be randomly selected.

The approximate quantity represented by each sample is specified in MT-601.

Additional samples may be selected and tested.

B. Lot Size. The concrete quantity in each day's production constitutes a lot whenever production schedules and material continuity permit.

The Project Manager may establish a lot consisting of the quantity represented by any number of consecutive random samples from three to seven inclusive if the Project Manager determines it is necessary due to production runs, significant material changes, or other unusual characteristics of the work.

C. Acceptance. Portland cement concrete pavement is evaluated for price adjustment on a lot-by-lot basis under Subsection 105.03.2, when deviation from specified aggregate gradation limits, fineness modulus limits for fine aggregate, or percent passing the number 200 sieve (0.075 mm) for coarse aggregate occurs on one or more tests for a lot.

Payment for a lot where a price reduction applies under the acceptance provisions in Subsection 105.03.2 is calculated using the following formula:

Price Reduction = Contract Unit Price x 0.40 x P/100 x Lot Quantity

Where:

P = the percent reduction in contract unit price as defined in Subsection 105.03.2.

Lot Quantity = the plan quantity in cubic yards (cubic meters) or square yards (square meters) of the pavement section where the lot was placed.

501.03.6 Mixing

Mix concrete meeting Subsection 551.03.3 requirements.

501.03.7 Transporting Concrete

Transport concrete in equipment meeting Subsections 501.03.1 and 551.03.4 requirements.

501.03.8 Placing and Finishing Concrete

Place all portland cement concrete pavement for projects of 20,000 square yards (16,720 square meters) or more, or bridge approach slabs, ramp tapers, and other small, restricted, or irregular areas, by the slip-form method.

Construct projects with 20,000 square yards (16,720 square meters) or less pavement using the slip-form method or by stationary side-form method using bridge deck finishing equipment.

Submit the proposed procedures and equipment details for the side-form method for approval before paving.

Place the fresh concrete on the prepared roadbed as close as possible in front of the paving machine to minimize concrete handling. Do not routinely use front-end loaders or other equipment at the paver for moving the fresh concrete once its placed on the roadbed.

Place concrete hauled in non-agitating equipment within 45 minutes from when the ingredients were charged into the mixer. Dispose of concrete that does not meet slump requirements at Contractor expense.

Place concrete hauled in agitator trucks within the time limits in Subsection 551.03.4(A).

Distribute the concrete to the specified slab thickness, with the finished surface at the specified grade, once the concrete is consolidated and finished.

Do not use vibrators to distribute concrete.

Place concrete only after the foundation course or subgrade has been approved by the Project Manager.

Prepare the foundation course ahead of the paving operation equal to the anticipated daily production.

Place concrete around manholes or other structures once the structures are brought up to the required grade and alignment.

Dampen the base or subgrade with a fine water mist immediately before placing concrete. Do not permit free-standing water to puddle on the surface.

If concrete placing is delayed or stopped in excess of one hour, construct an emergency transverse construction joint as directed.

Except for emergency transverse joints, do not construct a joint at any location other than as directed or specified.

Construct the pavement in full lane widths in a single operation.

Construct longitudinal joints between lanes or sections meeting Subsection 501.03.13(F) requirements.

Do not place concrete in longitudinal sections until the adjacent slab is 14 days old or has reached a minimum compressive strength of 2,000 psi (13,800 kPa), determined by testing the standard cylinders cured under the same environmental conditions as the slab.

A. Slip-form Method.

1. **General.** Place the concrete with a slip-form paver meeting Subsection 501.03.1(C) requirements that spreads, consolidates, screeds, and float-finishes the fresh placed concrete in one pass.

   Operate the slip-form paver to maintain a continuous, forward movement. Assure all concrete mixing, delivering, and spreading provides uniform progress without

stopping and starting the paver. If it is necessary to stop the paver, immediately stop the vibrators and tamping.

Maintain a uniform consistency in the concrete with a slump of 1-inch to 2-inch (25 mm to 50 mm).

The paver may be set to form a 3-inch (75 mm) or less battered edge while maintaining the top riding surface at the specified width.

Apply additional hand vibration at construction joints as required for consolidation.

2. **Finishing.** Finish the concrete surface to meet Subsection 501.03.14.

Correct any pavement edge slump, excluding specified edging, exceeding 1/4 inch (6 mm) before the concrete has hardened.

If the edge slump on any 1-foot (305 mm) or longer length of hardened concrete exceeds 1-inch (25 mm), remove and replace the entire panel between the transverse and longitudinal joints.

Before the initial concrete set, round the pavement edges on each side of the transverse expansion joints, formed joints, transverse construction joints, and emergency construction joints to the required radius. Construct a well-defined, smooth, dense mortar finish radius.

Hand finishing is permitted only for finishing sections with narrow irregular dimensions and to finish any concrete already deposited on the grade should a machinery breakdown occur.

Grind high spots exceeding 1/4 inch (6 mm) using approved methods. Fill low spots exceeding 1/4 inch (6 mm) with an approved epoxy-bonded grout as directed.

B. Stationary Side Form Method.

1. **Preparation of Subgrade or Foundation Course.** Once the roadbed is finished and compacted under Section 203, trim, shape, and compact the subgrade or foundation course meeting Section 301 to the specified lines, grades, and cross sections.

Extend the finished subgrade 2 feet (610 mm) beyond each side of the planned pavement width.

Once the forms are set, re-shape and re-compact all disturbed subgrade or foundation course using rollers or compactors working between the fine grading equipment and the paver.

Test the subgrade or foundation course in advance of the paver for section and grade using an approved template. Mount the template on visible rollers with the tooth edge conforming to the required shape of the subgrade when riding vertically on the forms. Remove excess material and fill low areas to the finish elevation with subgrade or foundation material and compact to the specified density.

Maintain the finished subgrade or foundation course in a smooth, compacted, undisturbed condition until the pavement is placed.

Moisten the subgrade or foundation course as specified in Subsection 501.03.8 when placing the concrete.

2. **Form Setting.** Do not permit the forms to deviate more than 1/8-inch (3 mm) from the true plane of the form face or top. Do not permit the forms to warp, bend, or kink. Clean and oil forms before each use.

Cut the compacted foundation course or the subgrade to grade providing firm contact for each form for its entire length at the specified grade. Fill low areas to grade in 1/2-inch (13 mm) lifts or less for 18 inches (460 mm) on each side of the base of the form and compact to the specified density. Settlement or springing of forms under the finishing machine is not allowed.

The forms will be checked for alignment and grade. Make any corrections before placing the concrete.

Correct unstable or disturbed forms or foundation courses and re-check the forms.

Prepare the foundation course and forms ahead of the paving operation equal to the average daily production.

Leave the forms in place at least 12 hours after the concrete has been placed unless earlier removal is necessary to permit sawing of transverse weakened plane joints.

Exercise care in removing forms to avoid damage to the pavement edges.

3. **Strike-off and Consolidation.** Strike-off, screed, and consolidate the concrete with mechanical equipment to the specified crown and cross section providing a uniform surface texture. Avoid prolonged work over any area.

   Maintain a uniform ridge of concrete ahead of the front screed of the finishing machine except when making construction joints.
4. **Floating.** Following strike-off and consolidation, finish the concrete surface with a mechanical float under Subsection 501.03.1(C)(8).
5. **Finishing.** Finish the concrete surface to meet Subsection 501.03.14(A) or (B).

C. Final Surface Finish. Hand-float the surface only as needed to produce a uniform surface and sharp corners. Do not use excess mortar to build up slab edges or round the slab corners. Before the concrete's initial set, work the pavement edges along each side of transverse isolation joints, transverse construction joints, and fixed forms to produce a 1/4-inch (6-mm) continuous radius and a smooth, dense mortar finish. Check the surface of the fresh concrete with a long-handled straightedge that is 10 feet (3 m) or longer. Remove high areas indicated by the straightedge.

D. Texturing. After surface finishing, texture all concrete surfaces within the travel lanes. Use either hand operated or mechanical tools to produce a uniform texture that conforms to the dimensions shown on the plans.

For artificial carpet and burlap drag, furnish carpet or burlap that is long and wide enough to cover the entire pavement width and that produces a uniform texture. Clean drag periodically to remove encrusted mortar or replace with new burlap or carpet.

Meet an average surface texture of 0.040 inch (1 mm) to 0.060 inch (1.5 mm), as measured by MT-113 (sand patch test).

If repair of high spots or low spots results in surface texture loss, repair the affected area to the specified texture at the Contractor's expense.

1. **Design Speed Greater than 50 MPH (80 km/h).** Produce the final surface finish with transverse tining, followed by longitudinal artificial carpet or burlap drag.

   Space transverse tines randomly as follows:

   - Minimum spacing 1/2 inch (10 mm);
   - Maximum spacing 1 1/2 inch (40 mm); and
   - No more than 50 percent of the tines apart by more than 1 inch (25mm).

   Use tines that are 1/8-inch (3 mm) wide, with a tolerance of ± 0.02 inch (± 0.5 mm) and apply them to a depth of 1/8-inch to 1/4-inch (3 mm to 6 mm) (provided minimum dislodging of the aggregate particles result).
2. **Design Speed Less than 50 MPH (80 km/h).** Produce the final surface finish by broom texturing, followed by a longitudinal artificial carpet or burlap drag.

   Produce a uniform texture with corrugations 1/16 inch (1.5 mm) deep.

501.03.9 Protection of Concrete From Rain

Maintain materials at the project site to protect all un-hardened concrete surfaces from rain.

When rain appears imminent, stop paving operations and cover all surfaces of the un-hardened concrete with the protective covering.

501.03.10 Evaluation and Repair of Rain-damaged Concrete

Follow *The American Concrete Paving Association Technical Bulletin No. 17* for the evaluation of and acceptable repair methods for rain-damaged concrete.

All protective, remedial, and corrective work to produce acceptable pavement is at Contractor expense.

501.03.11 Curing

A. Membrane. After the concrete is finished and the free water has left the surface, seal the entire surface area by machine spraying a uniform application of curing compound meeting Subsection 501.02.6 requirements.

Apply the curing compound following the manufacturer's recommendations before surface hair checking develops.

Do not apply curing compound to the inside faces of joints to be sealed.

If the groove coverage is not complete after the first application, apply a second coverage in the opposite direction from the first. Apply the second application within 30 minutes of the first application.

Assure the equipment controls the curing compound application rate and uniformity. Use the coverage rate of 1 gallon per 150 square feet (0.27 L per square meter) or follow the manufacturer's recommendations.

Re-apply membrane curing compound to areas protected for less than 72 hours and that are damaged by sawing, rain, or other causes.

B. Other Methods. The Contractor may submit for approval, other curing methods.

501.03.12 Handling and Placing Reinforcement

Keep reinforcing steel clean, rust free, straight and distortion free, placed and held in position as specified.

Store reinforcing steel out of the weather, distributing only the steel needed for immediate placing along the work.

Assemble and place reinforcement for bar mats as specified. Maintain bar mat placement during concreting operations. Tie all intersections. Lap all adjacent ends at least 40 bar diameters.

501.03.13 Joints

A. Transverse Expansion Joints. Construct transverse expansion joints as specified in the contract.

B. Expansion Joints at Structures. Construct and seal joints between concrete approach slabs and structures or concrete pavement as specified.

C. Transverse Construction Joints. Make transverse construction joints as detailed in the contract, at the end of each day's run, or where concrete work is interrupted for more than one hour.

Form the joint using a clean plank cut to the plan cross section with an attached beveled strip to form a key-way. Remove the header and clean excess concrete on the subgrade and joint face before placing fresh concrete against the joint.

D. Transverse Contraction Joints. Saw transverse contraction joints to the specified width, depth, and spacing using a power-driven gang saw with at least four separate blades.

Saw initial or "control" transverse contraction joints at 54 foot (16.5 m) intervals or another multiple of the specified joint spacing that reduces uncontrolled cracking with the least number of initial contraction joints. Saw initial contraction joints as soon as possible after the concrete is placed. Do not permit the saw to tear or ravel the adjacent concrete. Saw the remaining contraction joints typically within 24 to 48 hours after concrete is placed.

Be responsible for determining joint-sawing methods, sequences, and timing to prevent random cracking. Immediately revise methods that cause random cracking. Repair or replace concrete defects resulting from errors in the work methods at Contractor expense.

Repair or replace broken slabs, random cracks, nonworking contraction joints near cracks, and spalls along joints and cracks under Subsection 501.03.15.

Protect saw cuts in concrete 60 hours old or less from rapid drying using twisted paper, fiber or rope cords, waterproof covering, or other approved methods.

Have at least one stand-by saw in good condition and additional saw blades at the job site during sawing operations.

Cut curbs and gutters to the required depth to prevent erratic cracking.

Immediately after the joints are sawed, flush the groove with pressurized water and blow the groove out with compressed air to remove all dust, water, and slurry. Clean the groove using compressed air just before filling with joint filler.

Place hot-poured joint sealer in sawed joints to within 1/4-inch (6 mm) to 3/16-inch (5 mm) of the pavement surface when the pavement temperature is at least + 40 °F (4 °C).

Do not use polyethylene strips to form transverse contraction joints.

E. Longitudinal Joints. Saw longitudinal joints to the specified width and depth within three days of placing the concrete.

Do not use plastic tape as a joint sealer.

Saw and apply hot-poured joint sealer meeting Subsection 501.03.13(D) requirements.

Assure the finished joint alignment is parallel to the centerline of the pavement and does not have irregularities exceeding 0.04 foot (12 mm), measured by a 12 foot (3.6 m) straightedge, except for normal centerline curvature.

F. Key-way Longitudinal Joints. Construct key-way joints as specified when adjacent pavement slabs are constructed separately.

501.03.14 Surface Test

Test pavement surfaces exceeding 300 feet (91.5 m) long under (A) Profilograph. Test surfaces 300 feet (91.5 m) and shorter under (B) Straightedge.

A. Profilograph. Furnish a 25 foot (7.6 m) wheel base California type profilograph and a competent operator to measure the surface smoothness before joint sealing. Do not exceed a maximum 3 mph (4.8 km/h) operational speed. Calibrate, adjust, and operate the profilograph following the manufacturers instructions and California Test Method 526. Provide the Project Manager 24 hours advance notice before using the profilograph. The Project Manager will witness all profilograph recordings. The profilogram must record a scale of 1 inch (25 mm) to 25 feet (7.6 m) longitudinally and 1 inch (25 mm) to 1 inch (25 mm) vertically. Take a profile on a line parallel to and 3 feet (0.9 m) inside the outside edge of each traffic lane. Run the profilograph parallel to the pavement edge at all times. Additional profiles may be taken to define the limits of an out-of-tolerance surface. End the profiles 50 feet (15.2 m) from existing pavements, bridge ends, and intersections. The

acceptable lane section profile is an average profile index of 12 inches (305 mm) per mile (1.6 km) or less with each lane section being 0.1 mile (161 m) long. The Project Manager will determine the profile index using California Test Method 526. Remove all high points in excess of 0.3-inch (8 mm) in 25 feet (7.6 m) or less within each 0.1 mile (161 m) section using a method approved by the Project Manager. Re-profilograph re-worked sections. Acceptable sections are those having an average profile index not exceeding 15 inches (380mm) per mile (1.61km). Re-profile corrected areas to determine if the section has an average profile index of 15.

Contract unit price adjustments are made following Table 501-1. The Contractor may elect to perform corrective work to reduce the average profile index when it is less than the corrective index but greater than the incentive index. Incentive will not be paid on sections with an initial index exceeding 15.

TABLE 501-1

CONTRACT UNIT PRICE ADJUSTMENTS

ENGLISH	
Lane Average Profile Index (Inches per Mile-per 0.1 Mile)	**Contract Unit Price Adjustment**
Less than 6	$0.50 per square yard incentive pay
6 to 10	Contract Unit Price
10 to 15	$1.00 per square yard deduction
Over 15	Corrective work required
METRIC	
Lane Average profile Index (mm per 1.6 km-per 161 m)	**Contract Unit Price Adjustment**
Less than 150 mm	$0.60 per 1 square meter incentive pay
150 mm to 255 mm	Contract Unit Price
255 mm to 380 mm	$1.20 per 1 square meter deduction
Over 380 mm	Corrective work required

The price adjustment applies to the entire area of concrete for the 0.1-mile (161 m) lane segment. The area is computed using plan width for the 0.1-mile (161 m) lane segments. Sections of pavement less than 0.1 miles (161 m) are added to subsequent paving to provide a 0.1-mile (161 m) section.

No payment is made for any section with an average profile index exceeding 15 until it is re-worked and re-profiled to an average profile index of 15 or less. Re-work all areas not profilographed (50 feet (15.2 m) from bridge ends and intersections) with high points exceeding 0.3-inch (8 mm) in 25 feet (7.6 m) to 0.3-inch (8 mm) or less per 25 feet (7.6 m).

Complete all corrective work before measuring the pavement thickness.

Include all profilographing costs in the contract unit price for portland cement concrete pavement.

B. Straightedge. Use straightedge tests for sections of pavement less than 300 feet (91.5 m) in length. Once the concrete has hardened, test the pavement surface with a 10 foot (3 m) straightedge placed parallel to the pavement centerline.

Span each low spot and touch each high spot with the testing edge revealing all irregularities.

Correct all pavement showing a variation from the testing edge exceeding 1/16-inch per foot (2 mm per 305 mm) from the nearest contact point with the testing edge or showing a total variation exceeding 1/4-inch (6 mm) from the 10 foot (3 m) straightedge by grinding until the areas are within the above limits.

Where the grinding methods would result in an unsatisfactory surface or in a slab thickness less than specified, the affected pavement may require an adjustment in the contract unit price or removal and replacement under Subsection 501.03.20.

Perform all pavement corrections including removing and replacing of pavement at Contractor expense.

501.03.15 Correcting Spall and Cracks

Remove and replace pavement slabs cracked through the full depth into three or more parts.

Repair pavement slabs containing a single diagonal crack intersecting the transverse and longitudinal joints within 1/3 of the width and length of the slab from the corner by removing and replacing the smaller portion of the slab. Repair broken slabs as directed.

Groove and seal random cracks that penetrate the full depth of the pavement. Groove the top of the crack to 3/4-inch (19 mm) minimum depth and a width between 3/8-inch (10 mm) to 5/8-inch (16 mm) using an approved grooving machine. Use a vertical rotary-cutting machine that can follow the crack path and widen the top of the crack to the required section without spalling or damaging the concrete. Remove all loose and fractured concrete, and thoroughly clean and seal the groove with the sealant specified in the contract.

The Project Manager will determine what random cracks are tight, don't penetrate the full depth of the pavement and will be left undisturbed. When requested by the Project Manager, determine the crack depth penetration by drilling and inspecting cores at Contractor expense.

When a transverse random crack terminates in or crosses a transverse contraction joint, fill the un-cracked portion of the joint with epoxy-resin mortar or grout, and route and seal the crack.

When a transverse random crack nearly parallels the planned contraction joint and is within 5 feet (1.5 m) from a contraction joint, route, seal, and fill the crack with epoxy-resin grout or mortar.

When a transverse random crack is more than 5 feet (1.5 m) from the nearest contraction joint in the pavement, seal both the joint and the crack. Thoroughly clean the joints before filling with epoxy-resin mortar or grout.

Repair spalls by making a saw cut at least 1 inch (25 mm) outside the spalled area and to a minimum depth of 2 inches (50 mm). When the spalled area abuts a joint, make a saw-cut 2 inches (50 mm) deep or 1/6 the slab thickness, whichever is greater. Chip out the concrete between the saw cut and the joint or primary crack to solid concrete. Thoroughly clean the resulting cavity of all loose material. Apply a prime coat of epoxy-resin binder to the dry, cleaned surface of all cavity sides, except the working joint faces to be retained. Apply the prime coat by scrubbing it into the surface with a stiff bristle brush. Place portland cement concrete or epoxy-resin concrete or mortar immediately following the prime coat application.

For spalled areas abutting working joints or working cracks penetrating full depth, place an insert or other bond breaker to maintain the joint or crack during the patch repair.

501.03.16 Opening to Traffic

Do not permit traffic or Contractor equipment, excluding joint sawing and sealing equipment, on the concrete until flex beam test results indicate the concrete has developed a minimum 350 psi (2,415 kPa) modulus of rupture.

Prepare the concrete flex beams meeting AASHTO T-23 and test for modulus of rupture using AASHTO T-97.

One test set consists of three beams. Take the concrete for the test beams from different concrete batches for each 2,500 square yards (2,100 square meters) of concrete pavement and make at least two sets per day. Test the beam sets for modulus of rupture. Cure the test beams under the same environmental conditions as the pavement they represent. The pavement, represented by the beams, may be opened to traffic when the average modulus of rupture of the set exceeds 350 psi (2,415 kPa) and no individual beam's modulus of rupture is less than 300 psi (2,070 kPa).

The Contractor may select the time for testing the beams. Test the flex beams on or near the project, using Contractor furnished equipment and with a Department Inspector witnessing the tests.

Include all costs to make, cure and test the flex beams in the contract unit price for portland cement concrete pavement.

Opening to traffic does not constitute a final acceptance of the pavement. The pavement is accepted upon confirmation of the 28-day flexural strength. Repair all concrete damaged prior to the final acceptance at Contractor expense.

501.03.17 Integral Curb

Construct the curb monolithically with the pavement.

Construct the inside face of the curb true to the lines and grades in the contract using the finish specified for the concrete pavement, including longitudinal floating and burlap drag finishing.

Test the surface for longitudinal trueness with a straightedge while the concrete is still plastic. Meet the same surface requirements specified for the concrete pavement.

Continue concrete pavement joints through the integral curb at the same locations, of the same type, and constructed in the same manner.

Cure the integral curb as specified for concrete pavement.

501.03.18 Weather and Night Limitations

Place concrete at night only with the Project Manager's written approval.

Stop concrete work when the ambient temperature falls below 40 °F (4 °C) and do not resume until the ambient air temperature reaches 35 °F (2 °C) and is rising.

Do not place concrete on a frozen foundation course or subgrade.

Remove and replace all concrete damaged by frost at Contractor expense.

501.03.19 Protection of Concrete

Cover the concrete with an approved commercial insulating blanket, covering all pavement if the ambient temperature falls below 35 °F (2 °C) during the cure period. Leave in place for seven days.

The Project Manager may direct the leaving the blanketing in place beyond the seven-day curing period.

501.03.20 Pavement Thickness

Construct concrete pavement to the specified thickness. Tolerances allowed for subgrade construction and specifications that may affect thickness do not modify the thickness requirements.

A primary unit of pavement is the pavement area placed in each day's paving operations. Within a primary unit of pavement, there may be an area or areas that are determined to be a secondary unit or units of pavement, as specified in part (B), Thickness Deficiency Exceeding 0.07 Feet (21 mm). The primary unit area is reduced by the secondary unit area.

Thickness measurements are made in each primary unit of pavement with a minimum one measurement for each 1,000 feet (305 m) of traffic lane, or fraction thereof, of pavement placed. The number of thickness measurements within each primary unit, both longitudinally and transversely, are determined by the Project Manager.

Thickness measurement locations are determined by random sampling under MT-416. Thickness measurements are made using MT-106 to the nearest 0.01 foot (3 mm).

Pavement thickness variation is determined by comparing the actual thickness measured with the specified thickness. The variation is determined to the nearest 0.01 (3 mm) foot as either excess or deficient variation.

Secondary thickness measurements are made under part (B).

When portland cement concrete pavement is placed using wire-line control over a base course constructed under a previous contract, pavement thickness variation measurements are made from a taut string line placed transversely across the pavement between grade points for the wire-line controls. Measurements are made from the string line to the pavement surface at three points across the section. Deviations from the planned cross section are computed for each point. The deviations for the three points are averaged and represent the thickness variation for that section. Three random sections are measured for each 1,000 feet (305 m) of traffic lane, or fraction thereof, and are averaged to represent that portion of a primary unit.

These measurements are the thickness deviations for applying the requirements of parts (A) and (B) below.

Fill all remaining holes in the concrete pavement after the thickness measurements are made with concrete of the same quality as that used to construct the pavement, at Contractor expense.

A. Thickness Deficiency Not Exceeding 0.07 Feet (21 mm). If all of the deficient thickness variations in a primary unit do not exceed 0.07 feet (21 mm), the thickness variations in the unit are averaged algebraically to determine the average thickness deficiency. For determining the average thickness deficiency, an excess thickness variation of more than 0.03 feet (9 mm) greater than the thickness specified is considered to be 0.03 feet (9 mm) greater than the specified thickness.

For each primary unit of pavement that is deficient in average thickness, pay to the Department, or the Department will deduct from any monies due or that may become due the Contractor under the contract, a sum computed by applying the deficiency adjustment from Table 501-2 to the quantity of the unit.

TABLE 501-2

CONCRETE PAVEMENT THICKNESS DEFICIENCY

AVERAGE THICKNESS DEFICIENCY		PROPORTIONAL PART OF CONTRACT UNIT PRICE
Feet	**mm**	**Percent Allowed**
0.02	6	100
0.03	9	80
0.04	12	68
0.06	18	57
0.07	21	50

For average thickness deficiencies of less than 0.02 feet (6 mm), no deficiency adjustment is made.

Average thickness deficiencies greater than 0.02 feet (6 mm) are rounded to the nearest 0.01 foot (3 mm) and the deficiency adjustment made using Table 501-2.

B. Thickness Deficiency Exceeding 0.07 Feet (21 mm). For each deficiency variation in a primary unit exceeding 0.07 feet (21 mm), the Project Manager will determine from secondary thickness measurements the dimensions of the secondary unit area where the apparent thickness deficiency exceeds 0.07 feet (21 mm).

The determination of the limits of the secondary unit area are made by making one randomly located secondary thickness measurement in each pavement panel adjacent to the panel in which the original measurement in the primary unit was made. This method continues until the secondary unit area is bounded by panels in which the secondary measurement is deficient in thickness by 0.07 feet (21 mm) or less.

The secondary unit area is made up of entire panels only. Panels are the areas bounded by longitudinal and transverse joints and pavement edges.

If a transverse weakened plane joint has been omitted at the location where a volunteer crack exists, the volunteer crack is considered a transverse joint only if the adjacent pavement is not to be removed and replaced.

The Project Manager will determine within the limits of the secondary unit area, which panels will require replacement and which panels may remain in place using procedures (1) and (2) below:

1. At Contractor expense, remove and replace the deficient concrete pavement panels with new concrete meeting all contract requirements. If the area to be removed is not bounded by longitudinal or transverse joints, saw the weakened plane joints at Contractor expense at the locations designated by the Project Manager. Lower the subgrade or base to meet the full thickness requirements. Replaced pavement will be tested for thickness requirements using additional secondary measurements and is subject to all of the contract requirements.

2. The Contractor may leave deficient pavement panels in place if the panels meet all of the other contract requirements and pay to the Department 50 percent of the contract unit price per square yard (square meter) or cubic yard (cubic meter) for those pavement panels left in place, or the Department may deduct that amount from any monies due or that may become due the Contractor under the contract. The decision to leave a deficient panel in place will be by contract modification under Subsection 105.03.

The cost of all secondary thickness measurements made under this Subsection will be deducted from any monies due or that may become due the Contractor under the contract.

After eliminating the secondary unit area or areas and thickness measurements from consideration, the average thickness deficiency of the remainder of primary unit areas will be determined under Subsection 501.03.20(A). Secondary thickness measurements made outside of a secondary unit area will be used to determine average thickness variation in the remaining primary unit area in which the measurements are taken.

The Contractor is not entitled to any additional compensation or time extension due to these requirements.

If the Contractor believes that the number of thickness measurements made in primary unit areas by the Project Manager are insufficient to indicate the actual pavement thickness placed, the Contractor may request the Project Manager to take additional thickness measurements. The additional calculated variations will be averaged with the original variations to determine the average thickness variation.

The Project Manager will randomly select the location of all additional thickness measurements.

The cost of all additional measurements made will be deducted from any monies due or that may become due the Contractor under the contract.

501.04 METHOD OF MEASUREMENT

501.04.1 Area Measurement

Portland cement concrete pavement is measured by the square yard (square meter) to the nearest 0.1 square yard (0.1 square meter).

The measured width is from outside to outside of completed pavement, not exceeding the specified width or the width ordered by the Project Manager.

The length is measured along the centerline of the pavement surface.

Fillets for widened sections or at drainage structures and similar locations placed monolithic with the pavement are measured as pavement.

Areas constructed other than as pavement are deducted from the pavement area. No deduction is made for any fixture located within the pavement limits that has a surface area in the plane of the pavement surface of 1 square yard (0.80 square meter) or less.

Integral curb is not measured for payment.

501.04.2 Volume Measurement

Portland cement concrete pavement is measured in cubic yards (cubic meters).

The concrete in cubic feet (cubic meters) per batch is calculated by determining the weight per cubic foot (cubic meter) of a batch using Montana Test Method MT-509 and dividing the result into the total accumulated weight of cement, aggregates, and water used in that batch.

The volume of concrete per batch is determined at least twice daily.

The volume per batch for each day's paving run is determined by averaging all volume determinations made that day.

The volume of concrete for payment for each day's run is the total number of batches accepted and placed multiplied by the volume per batch as outlined above.

501.05 BASIS OF PAYMENT

Payment for the completed and accepted quantities is made under the following:

Pay Item	Pay Unit
Cement Concrete Pavement	Square Yard (square meter) or Cubic Yard (cubic meter)

Payment at the contract unit price is full compensation for resources necessary to complete the item of work under the contract.

SECTION 551
PORTLAND CEMENT CONCRETE

551.01 DESCRIPTION

These are the general requirements for designing portland cement concrete mixtures, the ingredients, mixing, placing, curing, testing and acceptance for all classes and uses of portland cement concrete.

Additional requirements and exceptions to these specifications may be found in other sections concerning the specific use of the portland cement concrete.

551.02 MATERIALS

551.02.1 Cement

Furnish low-alkali portland cement meeting the requirements of AASHTO M 85 or ASTM C 150, Type I, II, III, IV, or V, as specified.

Furnish Type I,II, or III cement for Class "Pre" concrete.

Do not use Type II-A cement.

Furnish portland cement meeting the following requirements:

1. The total alkali content does not exceed 0.6 percent, calculated as the percentage of sodium oxide (NaO) plus 0.658 times the percentage of potassium oxide (K_2O).
2. Use only one brand of any one type of cement on the contract except by written approval from the Engineer. Different brands or grades, if approved, cannot be used alternately in any one pour.
3. Store all bulk cement in metal silos, bins, or other approved storage. Provide storage facilities that permit convenient sampling and inspection. Store all sack cement in weatherproof buildings or, if approved, in the open on raised platforms with waterproof covering. Partially set, caked or lumpy cement will be rejected.

551.02.2 Air-entraining Agents

Include an air-entraining agent in the mix design. Ensure that the air-entraining agent meets AASHTO M 154 requirements.

551.02.3 Admixtures

Ensure that all chemical admixtures included in the mix design meet AASHTO M 194 requirements. Ensure that the total contribution of chloride ions from all admixtures and air-entraining agents does not exceed 50 parts per million chloride ions (Cl-) by weight of cementitious material.

551.02.4 Epoxy Adhesives

Furnish epoxy adhesives meeting ASTM C 881 or AASHTO M 234 and ASTM C 883 requirements.

Paragraph 1.4.8 of AASHTO M 234 is amended to permit thinning of epoxy for use in sealing ground deck slab areas only.

Furnish coal tar epoxy coating meeting AASHTO M 200 requirements.

551.02.5 Water

Obtain the Engineer's approval of the water to be used in the concrete. Assure the water does not contain oil, acid, alkali, vegative substances, and is not brackish or salty.

Questionable water will be tested by comparing the compressive strength of concrete cubes made with the water in question, against those of concrete cubes made with water of known quality.

The concrete cubes will be cast, cured, and tested for compressive strength under ASTM C 109.

551.02.6 Aggregate

Furnish aggregates meeting Subsection 701.01 requirements.

Store aggregates in compartmented bins, or other methods that separate the different aggregate sizes to prevent contamination. Suspend work for aggregate contamination until corrected.

Build up coarse aggregate stockpiles in successive horizontal layers not exceeding 3 feet (0.9 m) thick. Complete each layer before starting the next one. Re-mix segregated aggregate to the grading requirements at Contractor expense.

When ready-mixed concrete is furnished, the ready-mix company's stockpiled aggregates must meet the aggregate specifications. The Company must establish separate stockpiles for Department work if existing stockpiles do not meet specifications.

Do not use contaminated aggregate removed from stockpiles in the work.

551.02.7 Curing Compounds and Protective Coatings

Furnish concrete curing compounds and protective coatings and combination curing-protective coating compounds meeting Subsection 713.07 requirements.

551.02.8 Preformed Expansion Joint Fillers for Concrete

Furnish preformed expansion joint fillers meeting Subsection 707.01 requirements.

551.02.9 Blended Cements

When specified in the mix design, furnish Type IP, Type I (PM), or Type I (SM) cement meeting AASHTO M-240 requirements.

551.02.10 Fly Ash

When included in the mix design, furnish fly ash meeting AASHTO M-295 Mineral Admixture Class C or Class F, the chemical requirements of Table 1, and the physical requirements of Table 3 in M-295.

551.02.11 Microsilica

When included in the mix design, furnish microsilica meeting AASHTO M-307.

551.02.12 Metakaolin

When included in the mix design, furnish metakaolin meeting AASHTO M-295 Mineral Admixture Class N, the chemical requirements of Table 1 and the physical requirements of Table 3 in M-295.

551.02.13 Ground Granulated Blast Furnace Slag

When included in the mix design, furnish ground granulated blast furnace slag meeting AASHTO M-302.

551.03 CONSTRUCTION REQUIREMENTS

551.03.1 Classification

Concrete mixtures with prefixes "A" contain 1 1/2-inch (37.5 mm) size aggregate.

Concrete mixtures with prefixes "D" contain 3/4-inch (19 mm) size aggregate.

Concrete with prefixes "D" may be substituted for concrete with prefixes "A" when the mix design has been approved by the laboratory.

The following requirements govern:

A. Classes "A" and "D" Concrete. Classes "A" and "D" concrete are used for sidewalks, curbs, and slope protectors.

B. Classes "AD" and "DD" Concrete. Classes "AD" and "DD" concrete are used for all structural concrete.

Class "AD" concrete may be substituted for Class "DD" concrete with the Project Manager's written approval. Bid all structural concrete as Class "DD". If a substitution is made, changing back to Class "DD" must be requested in writing and receive the Project Manager's written approval.

C. Class “SD” (Special Deck) Concrete. Class "SD" (Special Deck) concrete is used for all superstructure concrete including deck slabs and barriers.

D. Classes "AP" and "DP" Concrete. Classes "AP" and "DP" concrete are used for concrete pavement on streets and highways.

E. Classes "AS" and "DS" Concrete. Classes "AS" and "DS" concrete are used for concrete deposited underwater that does not contain an air-entraining agent.

F. Class "Pre" Concrete. Class "Pre" concrete is used in all prestressed items.

G. Class "F" Concrete. Class "F" concrete is used for setting metal fence posts and braces and similar uses where high quality concrete is not necessary.

Obtain the Project Manager's approval for aggregates for Class "F" concrete.

H. Classes "AC" and "DC" Concrete. Classes "AC" and "DC" concrete are used for erosion control devices.

I. Flowable Fill. Use flowable fill for bedding, encasement, and general backfill for trenches. Flowable fill is also known as controlled low-strength material, controlled density fill, flowable mortar, and slurry cement backfill.

J. Air-entrained Concrete. Use air-entrained concrete in all parts of structures, except for Classes "AS", "DS", and “Pre" concrete.

Do not use an air-entrained portland cement.

1. **Air-entraining Agents.** Add the approved air-entraining agent to produce an entrained air content within the specified limits for the particular class of concrete.
2. **Entrained Air.** Provide the required air content for each class of concrete shown in Table 551-2.

Testing for the percent entrained air will be by MT-102 using concrete samples taken just before incorporation in the work.

551.03.2 Composition of Concrete

Furnish the names of proposed suppliers and locations of proposed aggregate sources upon receipt of the Notice of Contract Award. This information is not required for Classes "F", "AC", or "DC" concrete.

Coordinate with the Project Manager for submitting samples for testing.

A. Design. Design the concrete mix as follows:

1. Upon written request, the Department will furnish a preliminary laboratory mix design for each class of concrete. Use this mix design as a starting point for designing the final mix.
2. Design the concrete mix to meet Table 551-2 requirements. State the design proportions in terms of aggregates in a saturated, surface dry condition. Submit the proposed aggregate source and proportion computations. Submit a final mix design for approval.
3. Do not change the material sources without approval.
4. The following cementitious materials may be used as partial replacement for portland cement in the mix design.
   a. Fly ash may be included in the mix design for up to 20 percent by weight of the total cementitious material. Portland cement meeting AASHTO M 85, Table 1, may be used in place of moderate heat of hydration cement where fly ash is substituted.
   b. Microsilica may be included in the mix design for up to 5 percent by weight of the total cementitious material when a minimum of 15 percent fly ash is also included in the mix design or when the mix design uses Type IP blended cement.
   c. Metakaolin may be included in the mix design for up to 20 percent by weight of the total cementitious material.
   d. Ground granulated blast furnace slag may be included in the mix design for up to 20 percent by weight of the total cementitious material.

   Calculate the water-cement ratio as the total weight of water divided by the total weight of cementitious material.
5. Except when Type V cement is specified, blended cements meeting the requirements of Section 551.02 may be used in the mix design.
6. The mix design may include provisions that address special conditions of the project that would otherwise not be allowed. The following provisions may be included in the mix design:
   a. **Delayed Initial Set.** The mix may be designed for delayed set time to allow for long haul or other project conditions. When delayed set is included in the mix design, the time requirements for placing the concrete in final position contained in Subsection 551.03.4(A) may be replaced by time to final placement requirements included in the mix design. Include in the mix design information on the delayed set provisions of the design and specific time to final placement requirements.
   b. **Slow Strength Gain.** The mix design may include cementitous materials or other admixtures that result in slow strength gain. When a slow strength gain is included in the mix, include in the mix design a recommendation for the age in days at which the strength will be obtained. The recommended age must be no less then 28 days and no more then 56 days. Support this recommendation with test results. Upon acceptance, the recommended age will be used in all provisions that refer to 28-day strength.

B. Class "F" Concrete. Class "F" concrete is 1 part portland cement, 2 parts of clean, hard, sharp sand passing a #4 mesh (4.75 mm) screen, and 4 parts of clean, broken stone or gravel uniformly graded between the #4 mesh (4.75 mm) and 1 1/2-inch (37.5 mm).

Proportion the materials by weight or volume as approved.

Class "A" or "D" concrete may be substituted for Class "F" concrete.

C. Classes "AC" and "DC" Concrete. Classes "AC" and "DC" concrete is low slump concrete meeting Table 551-2 requirements.

Use broken stone or gravel uniformly graded between the #4 mesh (4.75 mm) and the maximum size sieve and clean, hard, sharp sand passing the #4 mesh (4.75 mm) sieve.

Proportion the materials by weight or volume as approved.

Class "A" or "D" concrete may be substituted for Classes "AC" and "DC" concrete.

D. Class "SD" Concrete. Produce Class "SD" concrete meeting Table 551-2 requirements.

Furnish coarse aggregate meeting the gradation requirements for No. 2 coarse aggregate in Table 701-4 in Subsection 701.01.2, with five percent maximum passing the No. 8 (2.36 mm) sieve.

E. Flowable Fill. Flowable fill is a mixture of portland cement, fly ash, fine aggregate, air entraining admixture and water. Flowable fill contains a low cementitious content for reduced strength development. Submit a mix design for approval. No compressive strength testing is required for the mix design.

Table 551-1 has the suggested mix guides for excavatable and non-excavatable flowable fill.

TABLE 551-1

FLOWABLE FILL MIX DESIGN GUIDE

MATERIALS	EXCAVATABLE	NON-EXCAVATABLE
Cement, Type I or II	75.6-102.6 lb/yd^3 (45-60 kg/m^3)	75.6-151.2 lb/yd^3 (45-90 kg/m^3)
Fly Ash	None	151.2-596.7 lb/yd^3 (90-355 kg/m^3)
Water	Mix designs must produce a consistency that results in a flowable, self-leveling product at time of placement.	Mix designs must produce a consistency that results in a flowable, self-leveling product at time of placement.
Air	5% to 35%	5% to 15%
Unit Weight (Wet)	2,430-2,970 lb/yd^3 (1,440-1,760 kg/m^3)	2,700-3,375 lb/yd^3 (1,600-2,000 kg/m^3)

Furnish fine aggregate meeting Subsection 701.01.1 requirements. The fine aggregate has no fineness modulus requirement.

High air generators or foaming agents may be used in lieu of conventional air entraining admixtures and may be added at the jobsite and mixed in accordance with the manufacturers recommendation.

The requirements for percent air, compressive strength and unit weight are for laboratory designs only and are not intended for jobsite acceptance requirements. Proportion fine aggregate to yield 1 cubic yard (1 cubic meter).

TABLE 551-2

CONCRETE PROPORTIONING TABLE

Class	Size of Coarse Agg, Square Mesh, Inches (mm)	Indicated Compressive Strength, 7-Day, PSI (MPa)	Minimum Required Compressive Strength, 28-Day, PSI (MPa)	Maximum Water / Cement Ratio (W/C)	Target Value for Slump, Inches (mm)[4]	Tolerance, Inches (mm)	Required Air Content, Percent
A	1 1/2 (37.5)	2,000 (14)	3,000 (21)	0.53	2 1/2 (60)	± 3/4 (20)	4-6
D	3/4 (19)	2,000 (14)	3,000 (21)	0.53	2 1/2 (60)	± 3/4 (20)	5-7
AD	1 1/2 (37.5)	2,000 (14)	3,000[3] (21)	0.53	2 1/2 (60)	± 3/4 (20)	4-6
DD	3/4 (19)	2,000 (14)	3,000[3] (21)	0.53	2 1/2 (60)	± 3/4 (20)	5-7
AS	1 1/2 (37.5)	1,600 (11)	2,400 (17)	0.53	6 (150)	± 2 (50)	—
DS	3/4 (19)	1,600 (11)	2,400 (17)	0.53	6 (150)	± 2 (50)	—
AP[1]	1 1/2 (37.5)	2,000 (14)	Note 3	0.53	1 1/2 (40)	± 3/4 (20)	4-6
DP[1]	3/4 (19)	2,000 (14)	Note 3	0.53	1 1/2 (40)	± 3/4 (20)	5-7
Pre[2]	3/4 (19)	—	5,000 (34)	—	—	—	—
F	1 1/2 (37.5)	—	—	0.53	—	—	—
AC	1 1/2 (37.5)	—	—	0.53	1 1/2 (40)	± 3/4 (20)	—
DC	3/4 (19)	—	—	0.53	1 1/2 (40)	± 3/4 (20)	—
SD	3/4 (19)	—	Note 3	0.40	2 1/4 (60)	± 3/4 (20)	5-7

Notes:

1. For concrete pavement, the 28-day flexural strength requirement is 500 psi (3.5 MPa) minimum, determined by AASHTO T9 (ASTM C 78).
2. For prestressed beams, the minimum compressive strength at transfer of pre-stress is 4,000 psi (28 MPa). The strength shown at transfer of pre-stress and the 28-day requirement are for standard beams and varies with beam length and design. Check plans and specifications for each project.
3. The minimum required compressive strength at 28 days listed in the table does not apply to Classes "AD" and "DD" concrete used in bridges and structures. The compressive strength for acceptance for Classes "AD" and "DD" concrete used in bridges and for Classes "AP", "DP", and "SD Modified" concrete is that specified in Subsection 551.03.7(C)(1).
4. The target value for slump may be reduced as necessary for concrete placed using slip-form methods. When included in the mix design, mid range or high range water reducers may be used to increase slump to facilitate placement.

551.03.3 Sampling, Handling, Batching, and Mixing

Produce each class of specified concrete from approved material batched in the proportions specified in the approved mix design.

Correct for moisture content variations. The fine and coarse aggregates are sampled using methods described in MT-201 using sample sizes used in MT-202.

The water may be proportioned by weight or volume. Proportion the cement, fine aggregate, and coarse aggregates by weight.

The Contractor may substitute approved volumetric measuring devices for weighing devices when batching aggregates for structures containing less than 10 cubic yards (7.65 cubic meters) of concrete.

Obtain the Engineer's approval of weighing methods before starting batching operations.

A. Water.

1. **Weigh Measurement.** Assure the weigh equipment measurements are not affected by pressure variations in the water supply lines. The Project Manager may require an auxiliary tank for filling the weighing tank.
2. **Metering.** Measure water volume by metering through a recording water-meter device, accurate to within plus or minus 1 percent of the required volume or plus or minus 1 gallon (3.8 L), whichever is greater.

Meter water for batching and mixing during warm weather operations.

The Project Manager may permit alternate methods of water measurement for cold weather work.

Completely discharge wash water from the mixer before starting any batching operation.

B. Cement and Aggregate. Proportion cement and aggregate by weight on all projects exceeding 50 cubic yards (38 cubic meters) for all classes of concrete.

Assure equipment for weighing cement and aggregates is accurate to within 0.5 percent of the true weight.

Weigh aggregates to within 1.5 percent of the total aggregate batch weight.

Weigh cement or fly ash to within 1.0 percent of the total cement batch weight. Weigh cement separately.

Equip scales for manual operation with a telltale dial or other device to show at least the last 50 pounds (23 kg) of load.

C. Batching Plant. Equip the batching plant with separate bins, weighing hoppers, and scales for fine aggregate and each size coarse aggregate.

If bulk cement is used, include a bin, hopper, and separate scale for the cement. Seal and vent the cement weighing hoppers to prevent dust escaping to the atmosphere.

Equip the batching plant with a non-resettable batch counter that indicates the number of batches proportioned.

A single weighing hopper with an accumulative scale is permitted if a separate scale is used for weighing the cement.

Batch plants must meet the requirements of having a separate scale for weighing the cement if:

1. The cement is always weighed in a separate inner hopper of standard manufacture design.
2. The cement is always batched and weighed first in the batching sequence.
3. Fly ash is batched separately by weight.

For projects exceeding 20,000 square yards (16,720 square meter) of portland cement concrete pavement, proportion aggregates and cement with equipment that weighs and records batch weights automatically.

Provide the Project Manager a printed record of each batch's weight for aggregate; cement; fly ash; volume of water and admixtures; the time mixing began; time batch discharged; haul unit number; and percent moisture in aggregate. The automatic batching equipment above may be used for smaller concrete volumes.

Provide each scale installation with 10 standard 50 pound (23 kg) test weights.

Locate the aggregate sampling device at the nearest practical point the aggregates enter the batching weigh bins. Obtain the Project Manager's approval of the sampling device before batching operations begin.

D. Mixers. Use mixers that combine cement, aggregates, water, and admixtures within the specified time to form a uniformly mixed mass.

Operate mixers following the manufacturers recommendations.

Assure the manufacturer's plate is prominently displayed on the mixer showing the drum capacity in volume of mixed concrete.

Repair or replace mixer blades worn more than 3/4-inch (19 mm) from the design dimensions.

Clean hardened concrete from the drum. Do not intermingle batches.

Uniformity tests on three consecutive batches will be performed on samples taken after 15 percent and 85 percent of the batch is discharged.

Table 551-3 specifies the maximum permissible variations in test results on samples from the two different portions of the same batch.

TABLE 551-3

ALLOWABLE BATCH VARIATIONS

TEST RESULT	VARIATION
Air Content - Volume, percent of concrete	1.0 percent
Slump	1.0 inch (25 mm)
Coarse Aggregate Content - portion by weight of each sample retained on No 4 sieve (4.75 mm)	6.0 percent
Average Compressive Strength at 7 days for each sample based on average strength of all comparative test specimens, percent (two cylinders will be molded and tested for each sample)	7.5 percent

Concrete is acceptable if test results in two out of three batches meet the limits for three out of the four tests.

Provide the facilities for sampling and arrange schedules for the sampling and testing.

Dump all concrete mixed less than the specified time outside the work or remove if incorporated, at Contractor expense.

Do not mix, transport, or place concrete using equipment with aluminum or aluminum parts that contact the concrete.

Concrete may be mixed in central plant mixers or in truck mixers meeting the following requirements:

1. **Central Plant Mixers.** Equip central plant mixers with an approved timing device, that automatically locks the discharge device when the drum is charged and releases the lock at the end of the required mixing period. The lock must have an audible warning device, which signals each time the lock is released.

   If the locking and timing device fails, the mixer may be used temporarily, provided the mixing time is increased 50 percent by using a clock or watch with a second hand located within full view of the mixer operator. Repair or replace the timing device within three working days.

   Equip mixers to have a positive mechanical device to prevent adding aggregate after the drum has been charged and mixing has begun.

   Mixing time for central plants is 90 seconds. The required mixing time may be reduced if the plant is capable of producing a homogeneous mix in a shorter time. Reduced mixing time will be approved only if uniformity tests meet Subsection 551.03.3(D) requirements.
2. **Truck Mixers and Agitators.** Use truck-mounted mixers having a closed, watertight revolving drum fitted with blades that thoroughly mix and completely discharge the concrete without segregation.

Assure the manufacturers plate showing the rated mixing, agitating capacity and the rated drum speeds for mixing and agitating is attached to the truck mixer and is legible.

Equip truck mixers with an accurate revolution counter that registers the drum revolutions. Mount the counter so it is easily read by both the operator and Inspector.

Equip truck mixers with a water-metering device that is accurate to within plus or minus one percent of the required volume or plus or minus one gallon (3.8 L), whichever is greater.

The truck mixer metering device is not required if all batch water is added at the plant or other location through an approved metering device.

Operate the drum at the manufactures recommended speeds.

Introduce water, cement, and aggregates at a central plant and add aggregates into the mixer in any sequence that produces a concrete meeting all contract requirements.

Batch cement and water simultaneously.

Water may be added at the job site provided its introduction is witnessed by an Inspector and the specified water-cement ratio is not exceeded.

If water is added at the job site, provide at least 20 additional mixing revolutions each time water is added before discharge.

Begin mixing immediately after introducing the cement and water and continue for at least 70 revolutions at mixing speed.

Assure at least 100 drum revolutions exceed 6 revolutions per minute. All revolutions exceeding 100 must be at agitating speed.

Keep the drum revolving continuously after the cement and water are introduced until it is discharged.

Do not use mixed concrete that has remained in the truck mixer drum longer than 10 minutes without agitation.

Concrete may be partially mixed by central plant mixing and completed by truck mixing. Central plant mixing must meet the requirements of Subsection 551.03.3(D)(1), except that the central plant mixing time may be reduced to 30 seconds. Continue the additional truck mixing between 50 and 80 drum revolutions at mixing speed.

E. Hand Mixing. Approval may be given to hand mix batches not exceeding 1/2 cubic yard (0.4 cubic meter) provided:

1. The hand mixing is performed on watertight platforms or containers.

2. The sand is spread evenly over the platform.

3. The cement is uniformly distributed over the sand and the two ingredients are thoroughly mixed dry using shovels until the mix is uniform in color.

Form the mix into a "crater", add water, turn and slice the entire mass until a uniform consistency is obtained.

Thoroughly wet the coarse aggregate, add it to the mortar, and turn and re-turn the entire mass at least 6 times until all aggregate is thoroughly covered with mortar and the mix is uniform in color and appearance.

Do not place hand mixed concrete underwater.

551.03.4 Transporting Concrete

Assure that the capacity of the plant and transportation equipment provides a delivery rate to permit handling, placing, and finishing of the work.

Time the delivery of loads to prevent the in-place concrete from taking initial set before succeeding layers or lifts are placed. Do not permit any layer or lift of concrete to remain exposed in excess of 20 minutes before being covered by fresh concrete.

Document the method and time of delivery by plant slips issued to the driver and signed by the Inspector at the plant. Deliver the slip to the Project Inspector upon arriving at the project.

A. Revolving Drum Mixers. Transport concrete in revolving-drum mixers meeting Subsection 551.03.3(D)(2) requirements.

Discharge the concrete at the job and place it in final position within 11/2 hours after introducing the mixing water and cement.

When the ambient temperature is 85 °F (29 °C) or above, place the concrete in final position within 1 hour after the water and cement are introduced.

B. Non-agitating Transportation Equipment. Do not use non-agitating transport equipment to transport concrete except when placing concrete pavement under Section 501.

551.03.5 Placing Concrete

Assure all reinforcement and other embedded items are clean and free from dried mortar, rust, scale, oil, or foreign matter before placing concrete.

Keep untreated forms and existing concrete in contact with fresh concrete wet at least 1 hour before placing the concrete.

Wash treated forms with a water spray immediately before placing the concrete.

Place concrete meeting the applicable requirements of Sections 501, 552, and 553.

Compact concrete into final position and consolidate it around fittings and embedded items.

Do not place fly ash or Type IP concrete cement in different parts of the same structure before obtaining the Project Manager's approval. Demonstrate that such use does not result in noticeable color changes or appearance.

Place flowable fill meeting the following requirements:

1. Place by chute or pumping and use a tremie when placing through water;
2. Place to the designated fill line without vibration or other compaction methods;
3. Do not place when the ambient temperature is below 35 °F (1.7 °C). Protect from freezing for a minimum of 36 hours after placement;
4. Use straps, soil anchors or other approved means of restraint when flowable fill is used for pipe backfill and other uses that may result in flotation, uplift or misalignment; and
5. Confine the flowable fill material within the designated placement area. Prevent intrusion damage to adjacent work areas and facilities from lateral hydraulic pressure of the fill during placement and prior to hardening. After placement leave the flowable fill undisturbed until the material has set.

551.03.6 Curing Concrete

Protect exposed concrete surfaces from premature drying by covering it with canvas, plastic sheets with sealed joints, burlap, sand, or other materials. Keep the concrete moist. Continually moisten uncovered surfaces by misting.

The concrete surfaces against forms may be cured by leaving the forms in place for at least seven days.

Protect concrete against freezing or other conditions harmful to strength development under the applicable requirements of Sections 501, 552, and 553.

To aid finishing, side forms on ornamental work, curbs and sidewalks, railings, and parapets may be removed between 12 hours and 48 hours after concrete placement.

Continue moist curing while finishing the concrete.

Keep the concrete surfaces moist after removing forms until surface repair is completed and one of the final cure methods described below is used. Surface repair includes removal of irregularities and repair of all depressions, voids, and air holes.

Cure concrete for at least seven days after the concrete is placed by either of the following methods.

A. Water Curing. Keep all finished top surface concrete moist with a fine water mist until the concrete has set. Keep the moist concrete wet with water or an approved curing cover.

Cure concrete deck slabs and concrete floors by placing burlap, cotton mats, or other absorptive material behind the finishing operation as soon as possible without marring the finished surface. Keep the absorptive material moist while in place.

The absorptive material may be kept in place for the entire curing period, or it may be removed as soon as practical and the entire surface covered with approximately 1 1/2 inches (40 mm) of sand, kept moist for the entire curing period.

B. Impervious Membrane Curing. Use Type 2 white-pigmented membrane curing compound on deck slabs and portland cement concrete pavements.

Use Type 1-D clear membrane curing compound with a translucent fugitive dye for other surfaces.

Deliver membrane-curing compound to the job in the manufacturer's original container, clearly labeled with the manufacturer's name and the contents.

Furnish clear curing compound, transparent and free from permanent color.

The clear compound must contain a fugitive dye that makes the film visible on the concrete for at least four hours after application but does not affect the concrete surfaces natural color after curing.

The compound must be ready to use as shipped by the manufacturer. Do not dilute the compound.

Do not use curing compound without providing the Project Manager a manufacturer's certification.

Pressure apply the curing compound, spraying it over the entire exposed surface in a minimum uniform film of one gallon per 150 square feet (0.27 L per square meter) of concrete surface. Pressurize the curing compound to produce a fine mist on the concrete during application.

Apply the curing compound immediately after the concrete finishing is completed.

If it is necessary that workers or equipment be on the concrete surface before the seven day curing period is complete, cover the sealed surface with a protective cushion. Use a cushion of moist, 1-inch (25 mm) minimum thick layer of fine sand or sufficient layers of moist burlap to prevent damage to the finished concrete. Cover the cushion with 4 feet by 8 feet (1,220 mm by 2,440 mm) sheets of 3/4-inch (20 mm) plywood. Do not place the cushion material until the final application of curing compound has been in place for eight hours.

Alternate cushion material may be approved by the Project Manager in writing. Layers of plastic, visqueen, or canvas are not permitted.

C. Application of Combination Curing and Protective Coating Compounds. When specified, uniformly apply a combination curing and protective coating compound meeting Subsection 713.07 requirements over horizontal surfaces such as pavements, bridge deck slabs, concrete floors, and sidewalks.

Use white-pigmented compound for pavements or deck slabs.

Use a clear compound containing a fugitive dye on curbs, sidewalks, barrier rail, and other superstructure components.

Thoroughly mix and apply the compound following the manufacturer's instructions or apply at a rate exceeding 1 gallon per 150 square feet (0.27 L per square meters).

Apply the curing compound immediately after the finishing operation using a self-powered machine with a mechanical pressure distribution system to provide uniform coverage. Equip the spray nozzles with hoods during windy conditions.

A hand-operated sprayer providing uniform coverage may be used to apply liquid curing compound to areas where a self-powered sprayer is impractical.

If the curing membrane is damaged from any cause during the curing period, re-coat the damaged areas immediately.

551.03.7 Testing and Acceptance of Concrete

A. Compressive Strength Testing.

1. **General.** A compressive strength sample consists of three test cylinders made at the same time from the same batch of concrete.

   The Contractor may make additional cylinders to determine strength gain and to maintain job control.

   Standard compressive strength tests will be made at seven and 28 days, except as specified below for concrete used in prestressed members and for Class "SD" concrete.

   The compressive strength results from one or a combination of the cylinders tested will determine if the concrete meets the required compressive strength in Table 551-2.

   Samples for making the cylinder will be taken following MT-105. Test cylinders will be cast and cured following MT-101 and tested meeting AASHTO T 22.

2. **Prestressed Concrete Members.** Standard compressive strength tests for Class "Pre" concrete will be made at 28 days. The average strengths of the three 28-day cylinders will determine acceptance under Subsection 551.03.7(C)(2).

   The Contractor may make additional cylinders to determine strength gain and to maintain job control.

3. **Class "SD" Concrete.** Standard compressive tests for Class "SD" concrete will be made at seven and 28 days. The average strengths of two 28-day cylinders will determine acceptance under Subsection 551.03.7(C)(1).

4. **Flowable Fill.** The Project Manager will determine when flowable fill may be covered based on the following:

   a. Supports the weight of a person weighing at least 155 lbs (70 kg) without deforming the surface, when placed beyond the traveled way; or

   b. After 24 hours or obtains 35 psi (240 kPa) penetration resistance as measured by a pocket penetrometer, when placed within the traveled way.

   Do not use flowable fill as a driving surface. Grade surface of flowable fill within the traveled way to allow for specified depth and type of surfacing material.

B. Flexural Strength Testing. In addition to the above compressive strength requirements, Classes "AP" and "DP" portland cement concrete pavements require beam tests to determine the concretes flexural strength.

The number of flexural strength tests required for acceptance is determined by the Department on a random basis. The flexural strength results from one or a combination of the beams tested will be used to determine whether the concrete meets the required flexural strength specified in Table 551-2.

Flexural beams made in the field will be cast and cured using MT-101 and tested under AASHTO T 97 (ASTM C 78).

C. Acceptance of Concrete. The concrete must meet all other specifications and the following:

1. Classes "AD", "DD", "SD", "AP", and "DP" Concrete. These classes of concrete placed in bridges and in concrete pavement are evaluated for acceptance on a lot-by-lot basis.

The concrete quantity placed in a single day for each class of concrete is divided into the number of equal quantity lots shown in Table 551-4.

TABLE 551-4

CONCRETE LOT QUANTITIES

CLASSES "AD", "DD", AND "SD" CU. YD. (m^3)	CLASSES "AP" AND "DP" CU. YD. (m^3)	NO. OF LOTS
Less than 200 (153)	Less than 1,000 (765)	1
200-399 (153-305)	1,000-1,999 (765-1,529)	2
400-599 (306-458)	2,000-2,999 (1,530-2,294)	3
600-799 (459-611)	3,000-3,999 (2,295-3,059)	4
800-999 (612-764)	4,000-4,999 (3,060-3,824)	5

Two sets of standard compressive test cylinders 6-inch x 12-inch (152 mm x 305 mm) or 4-inch x 8-inch (102 mm x 203 mm) will be made for each lot. Each set will be made from a sample taken from a single batch or load selected at random from all loads or batches in the lot. For concrete lots less then 30 cubic yards (23 cubic meters), the Engineer may elect to make only one set of standard compressive test cylinders to represent the lot.

Each set will consist of one cylinder for Classes "AD", "DD", "AP", and "DP" concrete and two cylinders for Class "SD" concrete.

Samples to make the cylinders will be taken following MT-105. Cylinders will be cast and cured using MT-101 and tested under AASHTO T 22.

Each set of cylinders is tested for compressive strength at 28 days. The test results for two cylinder sets will be the average of the strengths of the individual cylinders.

The strengths of other cylinders made from the sample and tested at earlier ages are not used for acceptance.

The lot acceptance strength is the average of the test results for the lot.

Each lot is accepted or rejected based on the lot acceptance test strength. The pay factor for each lot accepted is determined from Table 551-5.

TABLE 551-5

PAY FACTORS

LOT ACCEPTANCE STRENGTH - PSI (1 psi = 6.9 kPa)

CLASS	1.0	0.95	0.85	0.70
AP, DP, AD, DD	3,000 or >	2,850-2,999	2,700-2,849	< 2,700
SD	4,500 or >	4,300-4,499	4,100-4,299	< 4,100

The Contractor may request acceptance of a lot at the 0.95 pay factor in lieu of approved corrective work or removal and replacement.

Acceptance at the 0.85 and 0.7 pay factor instead of approved corrective work or removal and replacement will be on the Engineer's determination of the effects the

defective lot will have on structural integrity and durability specified in Subsection 105.03.

The concrete quantity in each accepted lot is paid at the contract unit price multiplied by the appropriate pay factor in Table 551-5.

The lot quantity for pay factors less than 1.0 is computed from:

a. Plan neat line dimensions of the portions of the bridge or bridges where the lot was placed; or

b. The plan area in square yards (square meters) of the section of pavement in which the lot was placed.

2. Class "Pre" Concrete. Class "Pre" concrete is evaluated for acceptance on a lot-by-lot basis based on the average of the 28-day compressive strength cylinders and variation in test results as measured by the standard deviation.

Each lot will be judged against the formula:

X - F'c + 0.35S

Where:

X is the average of three 28-day cylinder strengths.

S is the standard deviation of the strengths for the three 28-day cylinders.

F'c is the concrete strength required for final acceptance as specified in the contract.

A lot is defined as all the concrete that is placed in a single pre-cast prestressed member.

Lots with any actual average cylinder strengths less than that calculated from the above formula will be rejected.

Three 28-day compressive test cylinders will be made for each lot, and each 28-day test cylinder sample will be selected on a random basis from all batches or loads.

The strengths of other cylinders made from a sample and tested at an earlier age will not be considered for acceptance purposes.

The cylinders for acceptance will be cast under MT-101, sampled under MT-111 and tested under AASHTO T 22.

The cylinders will be cured within the curing enclosure under the exact conditions and methods used to cure the prestressed member until transfer of pre-stress. After transfer of pre-stress, the cylinders will continue curing under MT-101.

3. Classes "A", "D", "AS", and "DS" Concrete.

a. The average of all the 28-day strength tests representing each class of concrete, as well as the average of any 5 consecutive 28-day strength tests representing each class of concrete, must be equal to or greater than the required compressive strength.

b. Not more than one test in ten consecutive tests may fall below 90 percent of the required compressive strength.

c. On projects where less than 10 tests are made, not more than one test may fall below the required compressive strength. The average of all tests must be equal to or greater than the required compressive strength, and paragraph (d) below will not apply.

d. Not more than ten percent of all compressive strength tests may fall below the required compressive strength for each class of concrete used in each major structure.

e. Concrete represented by tests that fail to meet the requirements of paragraphs (a), (b), (c), and (d) will be rejected, unless it can be established by other methods

that the concrete is acceptable in place in the completed structure. Procedures to evaluate in-place concrete that has failed one of the above requirements will be approved by the Engineer. Submit these procedures in writing within 7 days after the last compression test representing the specific member. Include in the written procedure details of sampling methods, including sample locations, test methods and conditions, and proposed criteria to evaluate test results. Generally, nondestructive test methods such as the Swiss hammer and the Windsor probe will not be considered. The evaluation procedure must be approved in writing before any sampling or testing of concrete in-place.

f. Unsatisfactory concrete will be rejected. Remove and replace all rejected concrete at Contractor expense.

4. **Small Concrete Quantities.** The Project Manager may accept 7 cubic yards (5.4 cubic meters) or less of 3,000 psi (20.7 MPa) strength concrete without a formal mix design. Submit a batch proportion sheet to for approval before use. Class "SD" concrete is excluded from this exception. Furnish concrete under this exception meeting the slump requirements in Table 551-2.

551.04 METHOD OF MEASUREMENT

Concrete is measured by the cubic yard (cubic meter) under Subsection 552.04, unless otherwise specified.

Classes "AP" and "DP" concrete is measured for payment under Subsection 501.04.

Concrete used in pre-cast concrete products is measured for payment under Subsection 554.04.

Class "Pre" concrete is measured for payment under Subsection 553.04.

551.05 BASIS OF PAYMENT

Payment for the completed and accepted quantities is made under the following:

Pay Item	Pay Unit
Concrete	Cubic Yard (cubic meter)

Concrete is paid for at the contract unit price per cubic yard (cubic meter) under Subsection 552.05.

Classes "AP" and "DP" concrete is paid for under Subsection 501.05.

Concrete used in pre-cast concrete products is paid for under Subsection 554.05.

Class "Pre" concrete used in prestressed concrete members is paid for under Subsection 553.05.

Payment at the contract unit price is full compensation for all resources necessary to complete the item of work under the contract.

SECTION 552
CONCRETE STRUCTURES

552.01 DESCRIPTION

This work is constructing concrete structures, and portions of prestressed concrete, steel, timber, stone masonry, and composite structures.

552.02 MATERIALS

Furnish materials meeting the following Section and Subsection requirements:

Concrete	551
Reinforcing Steel and Structural Steel	711
Expansion Joint Filler	707.01
Water Stops	707.03
Compression Joint Seals	711.15
Fiber-reinforced Pads for Bearing Plates	711.16

552.03 CONSTRUCTION REQUIREMENTS

552.03.1 General

The classes of cast-in-place concrete used in bridge substructures, retaining walls, and superstructures are as follows:

- **A.** Class "AS" or "DS" for foundation seals and other underwater placement;
- **B.** Class "AD" or "DD" for retaining walls, substructure to the beam seats, backwalls, and diaphragms; and
- **C.** Class “SD” for decks, curbs, sidewalks, and barriers.

552.03.2 Foundations

Construct foundations meeting Section 209 requirements.

Place concrete only after the foundations are inspected and approved.

552.03.3 Falsework

Construct falsework that supports the concrete work without detrimental deformation or settlement and to the plan lines and grades.

Use piling to support falsework not on solid footings.

Temporary camber all spans allowing for shrinkage and settlement. The contract specifies those bridges that require a permanent camber.

Provide "Tattletales" or other approved devices at locations to indicate form settlement or deflection. Adjust falsework as required to maintain plan line and grade.

Stop the work if detrimental settlement occurs in the falsework that cannot be adjusted. Remove and replace all concrete work affected by detrimental settlement at Contractor expense.

The Contractor is responsible for the adequacy and execution of the falsework plans. Furnish a Contractor approved copy of the falsework plans to the Project Manager upon request. The Contractor approval must be shown on the drawings.

552.03.4 Forms

Construct forms so their removal does not damage the concrete.

Remove all forms and form members not designated to remain in place.

The term "exposed surfaces" means those concrete surfaces that are above the finished ground line.

Use metal or plywood forms for exposed surfaces, and countersink all bolt and rivet holes. Assure the forms are mortar-tight providing a smooth finished concrete surface meeting the specified shape. Rough lumber, tongue-and-groove lumber, and steel-framed wooden panel forms may be used for surfaces not exposed in the finished structure that do not adversely affect the strength or appearance of the finished structure.

Use only one type of material in any form or group of forms for exposed concrete surfaces on similar parts of a structure.

Use filleted forms for re-entrant angles. Chamfer forms 3/4-inch (20 mm) for all exposed corners and edges with an enclosed angle of less than 120 degrees.

Design the forms and falsework assuming the concrete has a liquid weight of 150 pounds per cubic foot (2,432 kg per cubic meter) minimum for vertical loads and 85 pounds per cubic foot (1,378 kg per cubic meter) minimum for horizontal pressure. Include in the design allowances for temporary construction loads.

Do not place concrete exceeding the designed form pressure.

Use forms for completed structures that are removable without disturbing adjacent forms.

Form marks must conform to the general lines of the structure. Column form marks may be horizontal or vertical or both, being as symmetrical as practical.

Provide form openings that permit ready access for form cleanout, inspection, placement, and compaction of the concrete. Provide cleanout ports at the top surface of the concrete where placing is stopped in narrow forms for walls or columns or where the bottom of the form is inaccessible.

Remove all extraneous material within the forms before placing concrete.

Treat the forms interior surfaces to prevent mortar adhesion.

Water soak wooden forms to close shrinkage cracks.

Set and maintain forms to the specified alignment, grade, and section and leave in place after concrete is placed for the specified time in Subsection 552.03.11.

Form defects are cause to stop work until corrected.

Fit metal tie rods or anchorages within the forms with cones or other devices that permit the rod and anchorage to be removed to 1-inch (25 mm) below the surface without damaging the concrete.

Use metal tie fittings that leave the smallest possible size cavities. Dry pack cavities with cement mortar to produce a sound, smooth, even finished surface closely matching that of the adjacent concrete after form removal.

Use deck slab forms that permit vertical adjustment of the bottom of the slab form.

552.03.5 Placing Concrete

A. General. Place concrete within the specified time limits in Subsection 551.03.4

Use an approved set-retarding admixture when ambient temperatures are expected to exceed 60 °F (15 °C) during deck slab concrete placement. Cement content reduction is not allowed.

Maintain the concrete temperature immediately before placement between 40 °F (5 °C) and 90 °F (32 °C).

Prevent concrete segregation and displacement of the reinforcement as the concrete is placed. Thoroughly clean all chutes, troughs, and pipes with water after each run. Discharge flushing water away from the forms and in place concrete.

Use metal or metal-lined troughs and chutes that extend to the point of deposit. Use a hopper or other device to regulate the discharge.

Do not allow concrete to drop from a height exceeding 5 feet (1,500 mm) unless it is within a conduit.

Support bars to maintain their position as shown in the contract.

Deposit concrete in small quantities at many points and then work or run it along the forms. Carefully fill each part of the forms, depositing the concrete as close as possible to its final position, working the coarse aggregates back from the face and forcing the concrete under and around the reinforcing bars. Do not allow concrete to fall through or over reinforcing steel, tie rods, or similar items.

Deposit concrete around steel shapes and closely spaced reinforcing bars, on one side of the steel, uniformly working it until the concrete flushes under the steel to the opposite side before any concrete is placed on the opposite side or over the steel.

Once the concrete has taken initial set, avoid jarring the forms or straining the projecting reinforcement ends.

Thoroughly consolidate all concrete, except seal concrete, during and immediately after depositing using mechanical vibration as follows:

1. Apply the vibration internally unless otherwise approved or as provided herein.

2. Vibrate the concrete at a minimum 4,500 impulses per minute or as recommended by the vibrator manufacturer.

3. The vibration must visibly affect the concrete mass, producing a 1-inch (25 mm) slump over a minimum 18-inch (460 mm) radius.

4. Use enough vibrators to compact each batch immediately after it’s placed.

5. Vibrate the concrete around the reinforcement and imbedded fixtures and into the form corners and angles.

Vibrate at the point of deposit in areas of freshly deposited concrete. Slowly insert and remove the vibrators from the concrete. Vibrate to thoroughly consolidate the concrete without causing segregation or forming localized grout areas.

Vibrate at uniformly spaced points and no farther apart than twice the radius over which the vibration is visible.

6. Do not apply vibration directly to or through the reinforcement or to non-plastic sections or layers of concrete. Do not use vibrators to transport concrete in the forms. Use plastic or rubber tipped vibrator heads when placing concrete near epoxy coated reinforcing steel.

7. Supplement vibration by spading and tamping to produce smooth surfaces and dense concrete along form surfaces, in corners and locations impractical to reach with the vibrators.

8. These requirements apply to precast piling, concrete cribbing, and other precast members unless the manufacturer's vibration methods are approved.

Place and secure all reinforcing, dowels, and other embedded items as specified before placing the concrete. Clean rust, scale, oil, dried mortar deposits or foreign material from all embedded materials before embedding in the fresh concrete.

Continuously place concrete in each section of the work in horizontal layers, working continuously if necessary, to prevent stoppage planes.

Place the concrete in layers to thoroughly consolidate them with the concrete beneath. Place the succeeding layer before the previous layer has reached initial set.

Compact each layer to prevent separation planes between the preceding layer and the layer being placed.

The Project Manager may require an emergency bulkhead if concrete placement in a section is delayed longer than 20 minutes.

A construction joint is any place where concrete placement has stopped and the concrete has taken initial set. Make construction joints meeting Subsection 552.03.7 requirements.

Inset construction joints where a "feather edge" might be produced in the succeeding layer. Provide a minimum thickness of 6 inches (155 mm) in all succeeding layers.

Place concrete so all construction joints are across low shear stress regions and out of view to the greatest extent possible.

Place deck slab concrete a minimum of seven calendar days after placing diaphragm concrete or when standard compressive strength test results verify that the diaphragm concrete has attained a compressive strength of 1,360 psi (9.5 Mpa).

B. Pumping Concrete. Use pumping equipment having the capacity required for the work and able to produce a continuous stream of concrete free of air pockets. Locate the pump to prevent vibration damage to fresh placed concrete.

Once pumping is completed, remove concrete in the pipeline to be used in the work without causing contamination or separation.

Use concrete pump discharge lines of at least a 4-inch (105 mm) diameter.

Do not permit aluminum pipe or pumping equipment with aluminum parts to contact the concrete.

C. Concrete Columns. Place concrete in one continuous operation, unless otherwise specified.

Allow columns to set at least 12 hours before placing the caps.

Place concrete in the superstructure after the column forms have been stripped and the column is inspected by the Project Manager.

The superstructure load may be placed on the columns when the column concrete reaches 80 percent of the required 28-day compressive strength, determined by testing standard 6-inch by 12-inch (152 mm x 305 mm) or 4-inch x 8-inch (102 mm x 203 mm) test cylinders.

D. Concrete Piling. Furnish concrete piling meeting Section 559 requirements.

E. Concrete Slab and Girder Spans. Place slabs and girders having spans less than 30 feet (9,145 mm) in one continuous operation.

Concrete slabs with girders spanning 30 feet (9,145 mm) or more may be placed in two operations, first placing the girder stems to the bottom of the slab haunches, and then placing the slab.

Use shear keys made of beveled timber blocks inserted at least 1 1/2 inches (40 mm) in the fresh concrete at the top of each girder stem. Place the blocks to uniformly cover about one-half of the girder stem top surface. Remove the blocks when the concrete has set enough to retain its shape.

Do not place the slab until the girders have been in place for at least 24 hours.

Check all falsework for shrinkage, settlement, and tighten all wedges to insure minimum deflection of the stems caused by the slab weight before placing the slab.

Place concrete in girder haunches less than 3 feet (900 mm) high at the same time as the girder stem.

When any haunch or filler has a vertical height of 3 feet (900 mm) or more, place the abutment or columns, the haunch, and the girder in 3 successive stages:

- First, up to the lower side of the haunch.
- Second, to the lower side of the girder.
- Third, to completion.

F. Concrete Slip-forming. Concrete barrier rails on bridges may be slip-formed.

Hand-finish the traffic face and top of the barrier to remove air holes and other blemishes, followed by a light broomed finish.

Sections with concrete slumps or bulges causing barrier rail misalignment or inadequate concrete cover for reinforcing steel will be rejected.

552.03.6 Depositing Concrete Underwater

Use Class "AS" or "DS" concrete for seals specified in the contract.

All costs for concrete placed outside of the plan dimensions and any change in the seal mix design for the Contractor's convenience is at Contractor expense.

Do not place concrete underwater without Project Manager approval.

When it is impractical or inadvisable to de-water an excavation before placing concrete, place a seal course underwater to seal the cofferdam. Place the entire seal in one continuous operation, meeting the following requirements:

- Use a tremie system; or
- Pump directly into a tremie hopper; or
- Pump directly to the deposit point.

Use tremie systems made of rigid, watertight steel tube having a minimum diameter of 10 inches (255 mm) with a hopper at the top. Keep the tremies discharge end submerged in the deposited concrete, and the tremie tube full to the hopper bottom at all times during the concrete placement. When a load is dumped into the hopper, raise the tremie to start the flow of concrete until the load discharges to the hopper bottom. Use a tremie support that allows free movement of the discharge end and permits rapid lowering of the tremie to retard or stop the flow.

Pump seal concrete meeting Subsection 552.03.5(B) requirements.

Have a backup concrete pump or tremie available at the site to insure uninterrupted placing of the entire foundation seal.

Pump concrete into a tremie meeting the placing requirements for tremie-placed concrete.

When concrete is pumped directly, the discharge tube must be a rigid pipe extending at least 5 feet (1,520 mm) above the water level during placement. The discharge line from the top of the rigid pipe to the concrete pump may be flexible.

Prevent water from entering the tube while placing concrete. Fill the tubes without washing the concrete.

Place concrete in a compact mass without disturbing it once deposited.

Do not place concrete in running water or expose it to the action of water before it has reached final set. Keep water still at the point of deposit.

Do not pump from the cofferdam while depositing concrete underwater.

Make all formwork retaining concrete underwater practically watertight.

Deposit concrete to produce horizontal surfaces.

After the seal concrete has cured and can withstand the hydrostatic pressure, de-water the cofferdam and place the remaining concrete in the dry.

Prepare the top surface of the foundation seal under Subsection 552.03.7 before joining fresh concrete to the seal concrete. Remove high spots to provide the clearances for reinforcing steel or projection of embedded piling.

552.03.7 Construction Joints

Obtain the Project Managers approval for construction joint locations.

If the concrete develops initial set due to placement delays, the stopping point is considered a construction joint.

Place concrete continuously from joint to joint. Make the joints perpendicular to the principal lines of stress and locate them at points of minimum shear.

Place a gauge strip, at least 2 inches (50 mm) thick, at all horizontal construction joints and at other directed locations inside the forms along all exposed faces to provide a straight line for the joints.

Before placing fresh concrete against set concrete, draw the forms tightly against the set concrete face and remove all gage strips and key forms. Remove all latence, loose and foreign

materials from the surface by sandblasting, high-pressure water cutting, or light bushhammering. Keep the surface moist until resuming concrete placement. Apply a thin coat of neat cement to the surface or coat as specified just before resuming concrete placement.

Bond the successive courses by keying or doweling, as shown in the contract, at the top layer of each day's work and at other points where work is interrupted.

552.03.8 Joints for Bridge Approach Slabs

Construct and seal joints between concrete approach slabs and structures or concrete pavement as specified.

Use forms for joints that are removable without damaging the concrete.

Protect the joint from damage and prevent debris and foreign material from entering the joint before installing the seal.

Limit construction equipment and other vehicles operated directly across the joint to rubber-tired equipment, unless approved joint protection is used.

Repair all spalls, fractures, breaks, or voids in the concrete joint surfaces as approved.

Before placing the seal, clean the joints by abrasive blast or other similar methods, followed with high-pressure air jets to remove all residue and foreign material. Protect expansion joint filler from the blast.

Make joint surfaces surface-dry when placing the seal.

552.03.9 Cold Weather Concreting

A. General. Assume all risk for placing concrete during cold weather. Replace frozen or damaged concrete at Contractor expense.

Cold weather is anytime the ambient temperature is expected to drop below 35 °F (1 °C).

Remove ice, snow, and frost from the forms and reinforcing bars before placing concrete. Do not place concrete on frozen ground.

B. Heating Fresh Concrete. Assure the temperature of fresh concrete is between 60 °F (15 °C) and 90 °F (32 °C) when placed.

Aggregates may be heated by steam or dry heat. Direct flame heating is prohibited. Eliminate frozen lumps, ice, and snow.

Do not add salt or chemical admixtures to the concrete to prevent freezing.

C. Protection of Concrete.

1. **General.** Maintain the air temperature surrounding fresh concrete at a minimum 60 °F (15 °C) for 7 days after placement or at a minimum 70 °F (20 °C) for 72 hours followed by 40 °F (5 °C) minimum for 96 hours. Place enclosures and heating equipment to maintain these temperatures before placing concrete.
2. **Deck Slabs and Barriers.** Protect and cure deck slabs and barriers placed after October 15 and before the following May 15 until the standard field-cured cylinders reach 90 percent of the specified minimum required strength.

   Maintain air temperatures surrounding the barriers and slabs between 50 °F (10 °C) and 120 °F (50 °C) during the cure period. Fully enclose the slabs and barriers on the tops, bottoms, and sides with space between the enclosures and the slabs and forms. Apply external heat as required to maintain the specified temperature within the enclosure.

   Insulated coverings placed directly on surfaces are not an acceptable substitute for the enclosure.

   Furnish and place recording thermometers at the locations designated by the Project Manager.

3. **Concrete Cured Under Water.** Substructure units other than those supported by falsework may be cured by a combination of heating and flooding. Maintain the air surrounding the concrete at between 60 °F (15 °C) and 120 °F (50 °C) for 72 hours after concrete placement. The unit may then be flooded with water for the remainder of the 7 day cure period if the water temperature exceeds 35 °F (2 °C). Maintain the air temperature surrounding any portion of the concrete remaining above water at 40 °F (5 °C) for the remainder of the seven-day period.

   Footings may be cured by flooding with at least 12 inches (305 mm) of water over the footing top if the water temperature stays at or above 35 °F (2 °C). Continue curing for 10 days after placement. Cure seals under water for at least 3 days before de-watering.

D. End of Curing Period. Lower the temperature within enclosures not to exceed 15 °F (10 °C) per hour until the inside and outside air temperatures are equal.

E. Heating Equipment. Block combustion heaters up off the concrete surface and vent them outside the enclosure. Assure heating equipment uniformly distributes heat around the concrete with the air temperature at the concrete surface never exceeding 120 °F (50 °C).

F. Field-cured Cylinders. Determine the number of field-cured test cylinders, to include a minimum 6 per each day's placement. Cast field-cured cylinders in single-use 6-inch x 12-inch (152 mm x 305 mm) or 4-inch x 8-inch (102 mm x 203 mm) round molds under MT-101. Protect the cylinders from moisture loss in the same manner used for the slab. Place the cylinders at the locations designated by the Project Manager and expose them to the same conditions as the slab until they are removed for testing.

Test field-cured cylinders within 36 hours after removal and not less than five days after casting under AASHTO T-22, except that the moist cure period is omitted. Perform tests using a certified testing laboratory. Furnish the Project Manager certified copies of the test results.

The Department may witness selected tests and testing procedures.

Two cylinders constitute a test with the test value being the average of the two compressive strengths. Continue curing and protection until the tests indicate the specified compressive strength is reached.

G. Recording Thermometers. Use recording thermometers that are automatic, continuous chart recording type. The range must be from 32 °F (0 °C) to at least 150 °F (65 °C) for conventional cure and 212 °F (100 °C) for steam cure. Each chart must cover a minimum of 24 hours and seven days maximum. Record only one cure period on each chart. Give the charts to the Project Manager at the end of each cure period.

Calibrate recording thermometers to the Project Manager's standard thermometer before each use and as directed.

Furnish thermometers, charts, calibration thermometers, and other equipment to maintain the thermometers.

552.03.10 Curing Concrete

Cure concrete under Subsection 551.03.6 and the applicable requirements of Subsection 552.03.9.

552.03.11 Removal of Forms and Falsework

Do not release, loosen, or remove forms or falsework without the Project Manager's approval. This approval does not relieve the Contractor of responsibility for the safety of work.

Approval to remove forms will not be given before the minimum times in Table 552-1.

The times in Table 552-1 are exclusive of days when the ambient temperature falls below 40 °F (5 °C); as the seven day curing period is based on a minimum curing temperature of 60 °F (15 °C).

The exact time lapse before forms may be removed will be determined by the Project Manager based on the site curing conditions of the concrete.

The Contractor may request, in writing, to use high early strength cement or a richer mix to reach concrete compressive strengths earlier and these times may be reduced as directed.

TABLE 552-1

MINIMUM CURE TIMES BEFORE FORM REMOVAL

ITEM	MINIMUM TIME
Walls, piers, and abutments (not yet supporting loads)	24 hours
Sides of columns, beams, and other comparable parts	24 hours
Railings	12 hours
Sidewalks on bridges	7 days
Slabs when supported on steel or wood stringers and precast concrete girders with unsupported span lengths less than 10 feet (3,048 mm)	7 days
Centering under crossbeams, girders, T-beams, caps, struts, box girders, top slabs on concrete box culverts, and slabs	14 days or 80% percent of the specified 28-day strength

Remove all forms, blocks and bracing. Remove mortar lips and all irregularities caused by form joints.

The presence of honeycombed areas may cause rejection of the work, and upon written notice, require removal and rebuilding of the work in whole or part at Contractor expense.

After the forms are removed, cut back and repair all projecting wires, tie bolts, and other metal form ties passing through the concrete meeting Subsection 552.03.4 requirements.

Repair honeycombed concrete in all parts of the work and voids and depressions in exposed portions of the work as follows:

1. Chip back all coarse and broken material to a dense, uniform concrete surface with exposed solid coarse aggregate.
2. Cut back feather edges to form faces perpendicular to the surface being patched.
3. Saturate all cavity surfaces with water, and apply a thin layer of neat cement.
4. Fill the cavity with a thick mortar mixed in the same proportions as the concrete used in the work and at the same temperature as the surface against which the mortar is placed.

Use a blend of portland cement, white portland cement and sand, proportioned to match the color of the concrete being repaired. Tamp the mortar into place, and float the surface using a wooden float before initial set takes place. Cure the patch under Subsection 551.03.6.

For patching large or deep areas, add coarse aggregate to the patching material to provide a dense, well-bonded, and cured patch.

Pull or remove all falsework piling 1 foot (305 mm) below the finished ground line or streambed unless otherwise specified.

552.03.12 Finishing Concrete

Finish all exposed vertical concrete surfaces to meet the ordinary finish requirements in Subsection 552.03.12(A).

Finish concrete bridge deck slabs and concrete curb and sidewalk surfaces to meet the requirements of Subsections 552.03.12(E) and (C) respectively.

A. Ordinary Finish. An ordinary finish is the concrete surface left once the forms are removed and all holes caused by form ties, trapped air, and all other defects are repaired. The finished surface must be true and even, free from stone pockets, depressions, or projections beyond the surface.

Ordinary finish is produced as follows:

1. Soak the concrete surface with water, and use the patching mortar specified in Subsection 552.03.11, working it into the small air holes and other voids in the concrete face with a sponge float or wooden float.
2. Rub off excess mortar after the mortar is partially set using burlap or carpet.
3. Remove uneven mortar surfaces that have set too hard by rubbing the entire surface with a carborundum stone and water.
4. Produce a finished surface that is uniform in texture and color.

Rub-finish all surfaces not repairable by the ordinary finish method meeting Subsection 552.03.12(B).

The ordinary finish may not be required for exposed vertical concrete surfaces listed below, if the forming produces a true and uniform surface and minor defects are repaired as specified:

1. Interior surfaces of box type concrete structures such as culverts, stockpasses, and minor grade separations; or
2. Concrete diaphragms for prestress girders; or
3. Pier shafts, abutment walls, columns, struts, crossbeams, or other substructure components located where they are not readily subject to public access or view. In general, substructure elements on bridges in undeveloped rural areas and more than 25 feet (7,620 mm) from the edge of the public road, located in or over streams not used extensively for recreation, or exclusively over railway property are not considered subject to public access and view.

Good forming practice is considered as:

1. Using materials with a smooth surface free from holes, tears, dents, and gouges;
2. Using the largest practical pieces to minimize joints;
3. Arranging joints to be vertically or horizontally symmetrical; and
4. Using bracing to prevent bulges, offsets, and other major defects in the concrete surface.

Repair major surface defects, and finish the substructure unit surface or other structural components to a uniform appearance.

Major surface defects are large rock pockets, offsets at form joints exceeding 1/4-inch (6 mm), bulges, projections and depressions that deviate from the surface plane by more than 1/4-inch (6 mm) in any 4 foot (1,219 mm) length, and all other defects that reduce plan reinforcing bar cover by more than 1/4-inch (6 mm).

Minor surface defects may be corrected without finishing the surrounding surface. Remove mortar fins even with the surrounding surface. Fill air holes exceeding 3/4-inch (20 mm) in the longest dimension with mortar and strike off even with the surrounding surface. Patch minor rock pockets, tie holes, and the like as specified in Subsection 552.03.11.

B. Rubbed Finish. After concrete has hardened, saturate the surface with water and rub using a medium-coarse carborundum stone with a small quantity of mortar on its face. Approved bonding agents may be used.

Use mortar consisting of cement and fine sand in the same proportions used in the concrete being rubbed.

When forms are removed while the concrete is "green", wet the surface and rub it with a wooden float. If approved the thin mortar described above may be used for rubbing.

Continue rubbing until all form marks, projections, and irregularities are removed, all voids filled, and a uniform surface is obtained. Keep the paste produced by rubbing moist and allow it to set for at least five days. Smooth the surface by rubbing with a fine carborundum stone and water. Rub to produce a smooth texture and uniform color over the entire surface. After the final rubbing is complete and the surface has dried, rub the entire surface with burlap to remove loose mortar. The finished surface cannot have unsound patches, paste, powder, or objectionable marks.

C. Broomed Finish for Curbs and Sidewalks. Finish the surface of concrete curbs and sidewalks to the lines and grades in the contract. Work the concrete until the coarse aggregate is forced into the body of the concrete and no coarse aggregate is exposed. Float the surface with a wooden float producing a smooth and uniform surface.

Apply a broom finish to curbs or sidewalks. Make the strokes square across the curb or sidewalk from edge to edge with adjacent strokes overlapped. Do not tear the concrete surface when applying the finish. Produce regular corrugations a maximum 1/8-inch (3 mm) deep.

D. Special Tooled Finish. Produce special tooled finishes using a bushhammer, a pick, a crandall, or other approved tool. Use air tools unless otherwise directed. Do not begin tooling until the concrete has set for at least seven days, or longer if necessary, to prevent "picking" the aggregate out of the surface. Produce a finished surface showing broken aggregate in a matrix of mortar, each aggregate particle being in slight relief.

E. Concrete Bridge Decks. Finish deck slabs by the machine method, excluding small or irregularly shaped areas where a machine is impractical.

1. **Machine Method.** Use a self-propelled transverse finishing machine to strike off and finish the surface of deck-slab concrete. Furnish the Project Manager information on the location and method of rail support, size of rail members, and a description of the machine.

   Trial-run the finishing machine over the entire deck area to be finished before placing any concrete. Make the trial run with the machine and rails set to the specified grade and section. Attach a spacer to the bottom of the strike-off 1/8-inch (3 mm) in thickness less than the concrete cover shown in the contract. Adjust the support rails to compensate for dead-load deflections in the bridge girders. Adjust transverse strike-off support rails to match any changes in the deck section. Make transverse rail adjustments to maintain the specified surface tolerances. Record trial run transverse rail adjustments for use during the deck finishing operations. Make all adjustments to maintain proper grade, section, concrete cover over slab reinforcement, and slab thickness before any concrete is placed.

   While placing the concrete, make enough strike-off passes to produce the required profile and section.

   Maintain the heading of concrete placement nearly parallel to and not more than 10 feet (3 m) ahead of the strike-off. The concrete carried ahead of the strike-off must not cause wheel slippage or other unsatisfactory operation.

   Orient the transverse axis of the finishing machine parallel to centerline of bearing on all pre-stress and steel girder spans skewed more than 15 degrees. Make the concrete placement heading parallel to the strike-off heading to produce equal loads on each girder.

2. **Hand Finishing.** Obtain the Project Manager's approval for hand finishing on deck slabs.

   Strike off concrete using a template or vibrating screed and finish to a smooth, even surface meeting the required profile and section using longitudinal and transverse floating. Power trowels are not allowed.

3. **Straight-edging.** Test the plastic concrete surface for surface smoothness behind the finishing machine with a 10 foot (3 m) straightedge. Assure the straightedge contacts the surface in successive positions parallel to the centerline of roadway across the entire slab width. Make longitudinal advances in maximum 5-foot (1,524 mm) increments.

   Immediately fill depressions with fresh concrete, consolidate, strike off, and finish. Remove high areas with a 10-foot (3 m) cutting straightedge and refinish. Correct all other surface defects using a 10 foot (3 m) float or combination float and cutting straightedge.

   Provide footbridge(s) that clear span the fresh concrete for complete finishing, texturing, curing, straightedge testing, and surface correction.

   Continue straightedge testing and surface correction until the entire surface meets the specified surface-smoothness requirements.

   Limited hand floating may be used to correct defects left by the finishing machine. Hand floating is not required if the machine-finished surface meets surface-smoothness requirements and is free of defects.

4. **Bridge Deck Surface Texture.** Texture the bridge deck surface with transverse grooves while the concrete is plastic. Use a hand or mechanically-operated comb or broom having a single row of steel tines spaced 3/4-inch (20 mm) center-to-center. Use tines of approximately 0.03-inch (1 mm) thick, 0.08-inch (2 mm) wide, and from 4 inches to 6 inches (105 mm to 155 mm) long.

   Operate the handheld texturing device from a footbridge. Make the application, the angle of tines with the surface, and the pressure on the concrete to produce a groove depth of between 1/8 inch to 3/16 inch (3 mm to 5 mm) without the grooves flowing together, tearing the surface, or displacing the coarse aggregate.

   Do not overlap successive passes of the texturing device.

   Terminate grooves 1 foot (305 mm) from the face of any curb or barrier. Skewed bridge decks may be textured parallel to the heading of concrete strike-off and finishing.

   The allowable surface smoothness variation is independent of the grooves formed by the transverse texturing.

5. **Broom Texture.** Hand-finish the traffic surface of curbs, sidewalks, and other horizontal surfaces to receive a broom finish under Subsection 552.03.12(E)(2). Manipulate the broom to produce a smooth, sealed surface meeting the specified surface-smoothness requirements.

   The texturing broom may be any medium-stiff bristled broom. Broom at right angles to the curb face or sidewalk and produce a uniform close spaced texture not exceeding 1/8 inch (3 mm) deep.

6. **Surface Smoothness.** The finished surface must not vary more than 1/8-inch (3 mm) from a 10-foot (3 m) straightedge placed parallel to the roadway centerline.

   High spots are measured as one-half the distance between the end of the straightedge and the pavement surface with the straightedge centered on the apex and the opposite end held in contact with the surface. Low spot variations are measured as the distance from the straightedge to the surface with the straightedge

centered on the low point. Correct unacceptable surface variations by grinding off high spots and patching or filling low areas.

Subsequent surface sealing will not be required where the grooved surface is produced using a diamond-faced saw-type cutter for grinding.

Perform surface sealing as follows for areas ground using conventional star-wheel-type cutters.

Seal all areas where removal exceeds 1/4-inch (6 mm) in depth with an approved, concrete-colored, low-viscosity epoxy-resin adhesive. Produce a non-skid texture using a steel-tine broom or by applying medium-coarse silica sand to the plastic epoxy surface. Meet the surface smoothness requirements.

7. **Protective, Remedial, and Corrective Work on Deck Slab Concrete.** Do not place concrete for deck slabs and stop work when rain appears imminent. Take immediate action to strike off all concrete in place to promote drainage and prevent ponding.

   Placing or finishing work that manipulates the concrete will not be allowed during precipitation.

   Deck slabs areas where precipitation has been incorporated into the concrete may be rejected. Make a maximum 3 light passes with a straightedge float to remove excess water after the precipitation stops.

   Protective work is that work necessary to protect unhardened concrete from damage by hail and rain. This includes covering the concrete with a protective covering when conditions warrant.

   Remedial work is that work to restore a surface profile and texture on unhardened, rain-damaged concrete. Concrete damaged by rain to the extent the texture is obliterated and has a sandy appearance may be repaired by removing excess water and restoring it to the specified surface smoothness and texture.

   Hardened concrete is concrete that is non-plastic and does not allow the vibrator to penetrate under its own weight.

   Corrective work is work to provide an acceptable profile and texture on hardened, rain-damaged concrete.

   Do not place fresh concrete against hardened concrete until a construction joint is placed under Subsection 552.03.7.

   Correct areas exceeding the specified surface-smoothness tolerance and areas where the specified texture cannot be produced by grinding and grooving using concrete grinding machines.

   Use a diamond saw type grooving machine.

   Grooves may be either longitudinal or transverse. Space grooves at 3/4-inch (20 mm) centers and be 1/8-inch (3 mm) wide by 1/8 to 3/16-inch deep (3 to 5 mm).

   Grooving is not required on areas that measure 10 feet (3000 mm) or less in length parallel to centerline of roadway.

   Do not grind or groove so that concrete cover is reduced over the top reinforcing bars to less than 2 inches (50 mm).

   Remove, replace, or overlay areas that cannot be corrected to the required surface smoothness and texture by grinding and grooving. Submit proposed overlay methods in writing to the Project Manager for approval before use.

   Remove all latence and hardened, excess concrete from construction joints before placing curbs, barriers, or other concrete.

   Furnish all protective, remedial, and corrective work to provide an approved deck slab at Contractor expense.

F. Bridge Seats and Tops of Walls. Bring the concrete at bridge seats and tops of walls up to the required grade elevation, strike off with a straightedge, and float to a smooth, uniform texture.

Slope the concrete surfaces in areas of bridge bearing assemblies to drain water away from the bearing devices as specified.

Bushhammering is permitted only for leveling the concrete surface under the bearing plate and removing latence and loose and foreign material. Bushhammer to produce full, level bearing.

Use steel shims when necessary to bring the masonry plates up to grade. Use shims of the same size as the masonry plate and a minimum 1/4-inch (6 mm) thick. When elastomeric bearing pads are used, perform the beam seat treatment specified in Subsection 556.03.19 using steel shims of the same size as the sole plate except for thickness. Place the shims between the sole plate and the elastomeric pad.

552.03.13 Installation of Expansion and Contraction Joints

Construct expansion and contraction joints meeting the contract requirements.

A. Open Joints. Construct open joints by inserting and removing a template made of wood, metal, or other approved material. Remove the template without chipping or breaking the concrete corners.

Do not extend reinforcement across an open joint unless specified.

B. Filled Joints. Construct poured expansion joints similar to open joints.

When pre-molded expansion joints are specified, the thickness of installed filler is specified in the contract. Match the joint filler to the shape and size of the surfaces to be joined and fix it firmly against the existing surface. Do not displace the joint filler while placing concrete.

Where more than one piece of filler is used to cover any joint surface, place the abutting pieces in close contact and join them together with a layer of asphalt-saturated roofing felt. Use a minimum 20-pound (1 kg per square meter) grade roofing felt having one side covered with hot asphalt.

The filled joints will be inspected immediately after the forms are removed. Neatly cut and remove all concrete or mortar that has sealed across the joint. Fill openings in deck slab joints during construction with an approved tar or asphalt as directed.

Place the necessary dowels, load-transfer devices, and other devices as specified.

C. Steel Joints. Fabricate and paint the joints as specified. Assure that the surface in the finished plane is true and free of warping.

Hold joints in the correct position during concrete placement.

Use the openings at expansion joints shown in the contract, correcting for installation temperature. Maintain the required clearance.

D. Water Stops. Place water stops as specified.

552.03.14 Placing Anchor Bolts

Anchor bolt holes may be drilled or formed.

Form bolt holes by inserting treated wood plugs or metal pipe sleeves into the plastic concrete and withdrawing the devices after the concrete has partially set. Form bolt holes at least 3 inches (75 mm) in diameter to allow for horizontal adjustment.

Drill holes at least 1 inch (25 mm) larger than the diameter of the anchor bolts. Verify hole size before setting the beams.

Assure all anchor bolts for shoe assemblies project above the plane of the substructure concrete to assure full anchor bolt and nut engagement after the final placement of the shoe assemblies.

Fill holes two-thirds full with an approved non-shrink or epoxy grout. Force the bolts down using uniform, even pressure or light blows with a hammer until the grout rises to the top of each hole and the anchor bolt nut rests firmly against the metal shoe or pedestal.

Determine the final anchor bolt locations, making allowance for thermal effects on the superstructure at the time of grouting.

Remove all excess grout, and clean the metal surfaces for painting.

Do not grout anchor bolts in freezing weather.

Make a written request to the use non-shrink or epoxy grout products formulated specifically for use at temperatures below freezing.

Protect bolt holes against damage from ice by filling with a non-evaporating antifreeze solution. Before grouting the bolts, remove the antifreeze and thoroughly flush the holes with clean water.

Anchor bolts for simple spans may be set to the exact location in fresh concrete. Correct all inaccuracies in bolt locations using approved methods at Contractor expense.

Install the anchor bolt nuts as shown on the plans. Tighten the upper nut against the lower nut so neither nut can be turned by hand.

552.03.15 Setting Shoes and Bearing Plates

Set shoes and bearing plates under Subsections 556.03.19 and 552.03.12(F).

Place masonry bearing plates on fiber-reinforced pads, sized and positioned to project a minimum of 1/2-inch (15 mm) on all sides of the bearing plates.

552.03.16 Drainage Holes and Weep Holes

Construct drainage holes and weep holes as specified. Place ports and vents for equalizing hydrostatic pressure where required.

Forms for weep holes through concrete may be wood, clay pipe, PVC pipe, concrete drain pipe, wooden boxes, or metal. Remove wooden forms, if used, after the concrete is placed. Paint or galvanize exposed metal drain surfaces as specified.

552.03.17 Pipes, Conduits, and Ducts

Install and rigidly brace pipes, conduits, and ducts encased in concrete before the concrete is placed.

Furnish and install 3-inch (75 mm) length plastic, PVC pipe or approved equal in the bottom slab at the low point of each box girder cell to provide drainage for each cell. Extend the pipe 1/4-inch (6 mm) below the bottom of the slab and flush with the slab's top surface.

552.03.18 Loading of Piers and Abutments

Do not place any superstructure load on finished bents, piers, or abutments until approved. The minimum time before any superstructure load is placed on the substructure is seven days, unless otherwise approved.

552.03.19 Opening to Traffic

Open concrete deck bridges to traffic only with the Project Manager's approval.

Do not open concrete bridge decks to traffic when the air temperature during the cure period is 50 °F (10 °C) or higher, until one of the following is met:

A. Twenty-one days after placing concrete unless standard strength test results indicate more time is required; or

B. Test results on field-cured test cylinders indicate that at least 90 percent of the required minimum strength has been attained. Two cylinders constitute a test, with the test strength being the average of the strengths of the two individual cylinders.

The Project Manager will determine the opening date when the ambient temperature during the cure period has been lower than 50 °F (10 °C).

552.03.20 Defective Work

Repair or replace all defective work at Contractor expense. Remove and replace the entire section at Contractor expense when the Project Manager determines the repair is not adequate.

552.04 METHOD OF MEASUREMENT

Concrete is measured in cubic yards (cubic meters) from the plan dimensions. Plan quantities will not be re-measured except as specified in Subsection 552.05.

Fillets, scorings, and chamfers 2 inches (50 mm) or less in the greatest dimension are omitted from the quantity calculations.

No deductions are made for the concrete volume displaced by reinforcing steel, structural steel, prestressed beams, anchor bolts, drains, weep holes, joint fillers, conduits, or junction boxes.

Deductions are made for the concrete volume displaced by timber, steel, and concrete piles. The timber pile volume encased by concrete is assumed as 0.8 cubic foot per foot (0.74 cubic meter per m) of pile.

When ordered in writing by the Project Manager, concrete quantities placed outside neat lines, are calculated and added for payment.

No measurement is made for forms, falsework, cofferdams, bracing, and the like.

552.05 BASIS OF PAYMENT

Payment for the completed and accepted quantities is made under the following:

A. The calculated quantities involved in changes ordered in writing by the Engineer are added or deducted from the contract quantities.

B. A re-calculation will be made and the corrected quantity included for payment, in lieu of the contract quantity, when the contract quantity of any complete structure element is in error by five percent or more. A complete structure element is the smallest portion of a total structure for which a quantity is included in the contract. The party to the contract requesting an adjustment in quantity must present to the other party three copies of the description and location and recalculated quantities of the structure element that has the quantity error.

C. Classes “AD, “DD”, and “SD” concrete placed in bridges are subject to a payment reduction based on lot payment factors under Subsection 551.03.7(C)(1).

Seal concrete, Class "AS" or "DS" is not under the lot payment factors.

Partial payments for structure elements will be made based on the contract quantities as follows:

1. 40 percent of superstructure concrete when deck forms are complete in place.

2. 80 percent when all types of concrete are placed.

3. 85 percent when curing is complete.

4. 95 percent when all finishing is complete.
5. 100 percent when the structure element area is cleaned up to the Engineer's satisfaction.

Pay Item	Pay Unit
Concrete	Cubic Yard (cubic meter)

Payment at the contract unit price is full compensation for all necessary resources to complete the item of work under the contract.

SECTION 553
PRESTRESSED CONCRETE MEMBERS

553.01 DESCRIPTION

This work is the furnishing and placing of precast, prestressed concrete beams, slabs, piling, and other structural members.

553.02 MATERIALS

553.02.1 Concrete

Furnish concrete meeting Section 551 requirements.

553.02.2 Reinforcing Steel

Furnish reinforcing steel meeting Subsection 711.01.1 requirements. Obtain the Engineer's written approval for reinforcing steel substitutions.

State on the fabrication drawings showing reinforcing steel details the following or similar words: "All dimensions are out-to-out".

553.02.3 Steel Rods and Bolts

Furnish rods used as dowels made from ASTM A 307 steel and bolts meeting Subsection 711.07 requirements.

553.02.4 Prestress Steel

Furnish high tensile strength steel wire meeting Subsection 711.11 requirements.

Furnish the typical load-elongation curves for all shipments of prestress steel to the fabrication plant.

Assure all prestress steel used in the work is free of rust, corrosion, dirt, oil, spatter from welding or flame cutting, kinks, bends, nicks, broken wires, or other defects.

Prestress steel is sampled under MT-111.

553.02.5 Enclosures

Use metallic enclosures, excluding aluminum, or forms using removable cores or ducts made of rubber or other approved material. Remove cores and ducts before installing the prestress steel.

Use enclosures that are mortartight and maintain their shape when subjected to loading.

Use enclosures that are 1/4-inch (6 mm) larger in internal diameter than the bar, cable, strand, or group of wires being enclosed.

Equip cores or ducts with pipes or other connections for grout injection when pressure grouting is specified.

553.02.6 Structural Steel

Furnish structural steel meeting Subsection 711.02 requirements.

553.02.7 Elastomeric Bearing Devices

Furnish elastomeric bearing devices meeting Subsection 711.14 requirements.

553.03 CONSTRUCTION REQUIREMENTS

553.03.1 Fabrication

Fabricate all prestress concrete members using a manufacturing plant currently certified by the Prestress Concrete Institute in the category applicable to the member being fabricated.

Furnish a copy of the plant's current certification in the applicable category along with the fabrication drawings for the elements to be fabricated.

The fabricator may prestress by pretension or post-tensioning the member, subject to the contract requirements.

Obtain written approval before changing the prestressing details.

553.03.2 Fabrication Drawings

Before casting members, submit fabrication drawings for approval. Show complete details of the method, materials, and equipment proposed for use in prestressing.

Include in the fabrication drawings the following information:

1. An erection layout of the members placed in the structure or structures with each prestress member assigned a production number. Mark each completed member with an assigned number;
2. A tentative fabrication schedule;
3. The proposed mix design, including admixtures;
4. The prestress steel manufacturer's name and the applicable specifications;
5. Details of the method and sequence of stressing including the numbered or lettered layout to be followed to stress the member. Show complete details of the proposed method for tensioning the draped strands. Include in the details gauge and elongation readings for initial, intermediate, and final tensioning, as well as the deflection sequence, where applicable;
6. Complete details, including anticipated camber, tensioning forces (initial and final), and required concrete strengths (transfer and 28-day);
7. A complete detensioning procedure for the castings;
8. Details of items to be incorporated into the beam, such as chairs, inserts, hold-downs, etc., listed by source, type, size or capacity, and supplier;
9. Show all items incidental to the beams, such as bearing plates, rocker assemblies, anchor bolts, etc., if supplied by the beam fabricator;
10. All information and data required for fabrication;
11. Show the tack welding procedures; and
12. Detail the use of all external weights or hold-downs if used. If weights are not required, note it on the fabrication drawings.

Show all changes from the prestressed details in the contract.

Submit design calculations of the system and method of production prestressing. Submit calculations on standard 8 1/2-inch by 11-inch (A4) paper.

Check and approve the fabrication drawings and design calculations before submitting. Show the Contractor's approval on the drawings.

Furnish all fabrication drawings on 22-inch x 36-inch (A1) paper with a 1 1/2-inch (38 mm) margin on the left side and 1/2-inch (13 mm) margins on the other three sides.

Do not begin fabrication until the drawings are Department approved and available at the plant.

553.03.3 Design of Concrete Mixtures

The prestressed girder concrete must have a minimum ultimate compressive strength of 4,000 psi (27.6 MPa) at transfer of prestress and 5,000 psi (34.5 MPa) at 28 days. The actual required strengths are specified in the contract.

Furnish a concrete mix design that produces concrete meeting the specified compressive strengths before use. Approved changes to the mix design may be permitted during fabrication.

Use a concrete design of between 6.5 to 8.0 sacks of cement per cubic yard (350 kg to 450 kg per cubic meter) of concrete.

Establish the Class "Pre" concrete slump range between 1-inch (25 mm) and 4 1/2-inches (115 mm). The high and low limits of the range may not exceed 1 1/2-inches (38 mm). The range may be changed with the Engineer's approval.

553.03.4 Forms

Use steel side and bottom forms. End bulkhead forms may be steel or plywood.

Form joints and strand exits through bulkhead forms that are mortartight.

Check the grade and alignment of side forms before casting. Check the beam bed alignment for displacement while placing the concrete.

Construct beam bed forms to limit movement to not exceed 1/4-inch (6 mm) from a straight line in any 50-foot (15.25 m) length of the bed.

Use clean forms that are free from warp, bulge, and other defects.

Do not exceed a maximum offset of 1/16-inch (2 mm) where form sections are joined.

Treat the form facing with a bond breaker before each casting. Form treating materials that stain or react with concrete are not permitted. Apply form oil or other bond breaker materials without contaminating the prestress strand and reinforcing steel. Clean soiled strand or reinforcing with a non-contaminating solvent.

Chamfer all exposed concrete edges, excluding the beam top, with an enclosed angle of less than 120 degrees. Use chamfer strips having no irregularities, and maintain smooth joints with the chamfer tightly fitted against abutting forms.

Fit forms with a grade strip or other positive control to establish the nominal depth of the beam.

Use forms that can be removed from the member without damaging the concrete.

Identify production form dimensions that vary from the contract beam dimensions on the fabrication drawings.

553.03.5 Placing Reinforcing Steel

Place and secure all reinforcing steel as shown on the plans before placing concrete.

Fasten all bars at all intersections with adjacent bars.

Do not tack weld reinforcing steel if the reinforcing bar is a stress-carrying member. Welding non-stress reinforcing bars may be permitted with the Engineer's approval. Reinforcing steel welds not shown on the approved tacking detail or fabrication drawings are prohibited.

For convenience, additional reinforcing steel may be tied in for securing inserts, void ducts, etc., or may be secured by tack welding.

Protect the tensioning strand from weld spatter using wet burlap or other protective covering. Replace all strands with weld spatter at Contractor expense.

Provide the distance between the reinforcing and side forms using approved stays, ties, or chairs. Do not use precast mortar blocks, pebbles, pieces of broken stone or brick, metal pipe, or wooden blocks.

Provide clearance between the beam stirrups and the beam bed using metal chair supports with stainless steel or other approved, corrosion-resistant legs.

Use reinforcing steel in the ends of prestressed beams to provide clearance for the paving notch blockout, void ducts, embed plates and anchorages, and inserts without interfering with the reinforcement spacing.

Reinforcement in the prestressed member will be inspected in place and approved by the Inspector before the concrete is placed. Concrete placed before inspection may be rejected.

553.03.6 Prestressing Equipment

Use approved jacking equipment for prestressing.

Equip hydraulic jacks with pressure gauges. Have a certified testing laboratory calibrate each jack and gauge combination as a unit with the cylinder extension in the approximate position that it will be in at the final jacking force. Have a certified calibration chart for each jack.

Other types of jacks may be used with proving rings or other approved devices calibrated by a qualified testing laboratory.

Calibrate jacking equipment once each year and after each repair. Re-calibration may be required if any jack or gauge gives erratic results or if the difference between the gauge reading and elongations exceed allowable limits.

Equip tensioning systems with hydraulic gauges that prevent the gauge pointer from fluctuating until the jacking load is released from the tendon. The gauge must read loads directly in pounds (Newtons) or have a chart to convert the dial reading into pounds (Newtons). Assure the gauge readings are accurate to within plus or minus two percent.

Locate the gauges to provide the operator and Inspector a clear view of elongation measurements and gauge readings. Use gauge dials graduated in increments not exceeding 100 pounds (700 kPa) pressure. The gauge range or load cells must not use the lower 10 percent of the manufacturer's rated capacity in determining the jacking stress, unless calibration data establishes accuracy within the two percent requirement at the lower range.

Assure the end anchorages and prestressed member stressing blocks can maintain the required tension in all prestressed tendons until the concrete has been placed and reached transfer strength. Equip the end anchorages and stressing blocks to detect deflection while prestressing. The Inspector will check for deflection.

Provide the equipment to determine concrete compressive strengths at the location the prestressed members are manufactured. The test equipment may be mechanical or hydraulic, capable of applying and measuring the required load. Error for loads within the loading range of the test equipment may not exceed an error of plus or minus 1.5 percent. Have a certified calibration diagram covering the entire use range with the equipment at all times. The indicated load of the testing equipment does not have to be corrected by calculation or by the calibration diagram to obtain values when the values are within the required variation of +1.5 percent.

Certify the concrete strength testing equipment every two years; after each repair or adjustment of the equipment; when a non-portable machine has been moved; and whenever accuracy is in question.

553.03.7 Pretensioning

Hold the prestressing elements in position using jacks when stressing. Keep a record of the jacking force and the elongations.

Multiple units may be cast in a continuous line and stressed at one time. Leave a space between the ends of the units to permit cutting of the strands.

Furnish strand in coils, reel-less packs, or on reels. Stringing may be performed by pulling single or multiple strands. Pull to gradually relieve strand rotation on coil or reel-less packs.

Strand with gripped points are not permitted within the lengths to be stressed.

Bring all prestress tendons to the uniform initial tension on the approved fabrication drawings. Initial tension is the minimum force required to equalize stresses and eliminate slack in the strand. Submit alternate initial loading proposals for approval.

The initial load may be applied by the jack used for single strand tensioning or by any other approved method that provides a definite, uniform load. Regardless of the method used, measure the initial load within plus or minus 100 pounds (450 N). Compute elongation measurements for initial tensioning but do not use as a measurement of the initial force.

Once initial tensioning is complete, reference mark the strand as directed. The mark must provide an accurate measurement of elongation by final tensioning.

Measure the induced stress by gauge and check it by elongation, load cell, or both. The results must agree within five percent. Do not permit jacking stress to exceed 75 percent of the specified minimum ultimate tensile strength of the prestressing steel. Measure the strand elongation to within 1 percent of the theoretical elongation or 1/8-inch (3 mm), whichever is smaller. If a discrepancy between measured elongations and gauge readings exceeds 5 percent, check and correct the entire operation before proceeding with the work.

All uplift devices, hold-down devices, and strand openings in end bulkheads must have rounded, smooth surfaces at all contact points with the strand.

Take gauge readings, elongation measurements, and make calculations for elongation and include allowances for operational losses for the tensioning system used. These allowances must include losses for strand slippage, anchor movement, friction, strand rotation, and other forces acting on the strand.

If the temperature difference between the strand at the time of tensioning and the concrete at the time of pouring exceeds 30 °F (16 °C), correct the computed elongation measurements for the temperature differences.

Provide copies of the elongation calculations to fabrication and inspection personnel at the beginning of production to insure all allowances for the method of tensioning have been considered.

553.03.8 Final Tensioning

A. Single Strand Tensioning. After the initial load is applied and the reference marks are established, individually pull the strands to the final load. Tension each strand to the load required by the gauge reading.

The elongation measurement must be within plus or minus five percent of the load indicated by the gauge reading. If the load indicated by gauge reading doesn't agree with the measured elongation within the required tolerance, discontinue tensioning and inspect the bed for restrictions that could affect the accuracy of the applied load.

If the measurements agree, three more strands may be tensioned. If elongation measurement and gauge readings are within the required tolerance, the remaining strands may be tensioned.

As some variation in the modulus of elasticity and the cross-sectional area of a strand does exist, the strand tensioning may be accepted, if the difference between the load determined by elongation and that indicated by the gauge does not exceed five percent. A maximum 10 percent of the total number of straight strands for any one line of casting will be accepted on this basis.

If the difference between the elongation load and gauge readings exceed the limits, discontinue tensioning and correct the problem.

B. Multiple Strand Tensioning. Mark each strand, once pre-loaded and seated in the anchorage, at both end anchorages to determine elongation and slippage. The Inspector will establish references to verify parallel movement.

Measure the stressing force by the gauge system and check it by the elongation measurement.

Use two load cells to verify the applied design load and check the uniformity of pull. Place one load cell on each side of the line of pull, preferably on the outermost strands of an upper row of straight strands.

If the hydraulic gauge and the load cells agree with the elongation measurements within plus or minus five percent, the strands are acceptably tensioned. If the gauge

reading is within five percent but either or both of the load cells exceed that limit, re-tension the strands including pre-loading. Locate and place the load cells on the strands nearest to those previously gauged.

If, upon re-tensioning, the load cells are within the five percent tolerance, no excess strand slippage has occurred, and the movable anchorage has traveled the required distance, the tensioning may be accepted.

If the difference between the gauge readings, load cell readings, and elongation measurements exceed the tolerance limit, stop tensioning and correct the problem.

Lubricate the jacking ram or rams, guide rods, and movable anchorage rails to minimize friction and run the ram through its length of travel at least four times before tensioning the strand.

C. Tensioning Draped Strands. Draped, pre-tensioned strands may be tensioned by partial jacking at the stressing block and subsequent depressing or uplifting to the deflected position or by tensioning to the initial and final loads with the tendons held in the final design position using pins, rollers, or other devices. Use low-friction devices at all points of slope change of the draped strand.

When draped strands are partially tensioned in the straight condition and then depressed to the final design position, determination of the final load is made as follows:

1. Before starting the tensioning operation, place a load cell at the dead end anchorage on one of the strands to be deflected in each line of beams.
2. The Inspector will select the strand to which the load cell will be placed.
3. Once tensioning is complete, the load cell reading must be within plus or minus six percent of the final design load.

Should the load cell reading exceed the allowable tolerance, use additional deflecting jacks to distribute friction and restraint at the deflection points or, if necessary, revise the entire method for applying the final design load within tolerances.

If the tensioning of draped strands indicates readings within the tolerances, the Inspector may require load cells for occasional checks.

If tensioning of the draped strands is performed by partial tensioning and uplift or, by tensioning in the draped position, submit the method for approval before use.

Strand splicing using approved devices is permitted. One splice is allowed on any one strand between anchorages. Splices must not fall within a beam. For single strand tensioning, the number of strands spliced is not restricted. When multiple strand tensioning is used, the number of strands spliced may not exceed ten percent of the total number of strands in the casting line, or all the strands must be spliced.

Use only one manufacturer's strand in any one tensioning operation.

Use the same direction of twist of strand wires in all spliced strands.

One wire failure in seven wire strands may remain in the casting, subject to the following:

1. For beams with:
   - **a.** Less than 20 strands.....No wire breaks permitted
   - **b.** 20 to 39 strands .....1 wire break permitted
   - **c.** 40 to 59 strands .....2 wire breaks permitted
   - **d.** 60 or more strands.....3 wire breaks permitted

Should wire breaks exceed these limits, or more than one wire break in any individual strand, remove and replace that strand or strands.

Locate all wire breaks allowed to remain in the casting, and securely wrap the broken ends with tie wire to prevent unraveling.

The Fabricator may be ordered to check the prestressing steel in a tensioned member for loss of prestress before placing concrete. The Engineer will approve the checking method for loss of prestress. Re-tension all strands showing a loss of prestress exceeding three percent of the original computed jacking stress.

Except as permitted in Subsection 553.03.5, do not weld, flame-cut, or ground welding equipment to the bed or forms after the prestress strand has been tensioned.

553.03.9 Placing Concrete

A. General. Batch and mix concrete under Subsection 551.03.3, except as provided below:

1. Provide master batch sheets to the Project Manager for review before production.

2. A timing device that locks the discharge gates of a stationary mixer is not required, however, the mixer must not be emptied until the materials have been mixed the specified time.

3. Ready-mix delivery slips are not required unless specifically requested.

The batching operation and equipment may be inspected at any time. The work will be stopped for failure to use approved procedures or equipment.

B. Method and Manner. Place concrete meeting Subsection 552.03.5 requirements and the following.

Obtain the Project Manager's approval before placing concrete in large members. Concrete may be placed in the member in a single lift if satisfactory results are obtained, or in multiple horizontal lifts provided cold joints are not formed. Remove and replace concrete containing cold joints. When concrete is placed in layers, place the first lift to fill the form slightly above the juncture of the bottom flange and the beam web.

Compact the concrete immediately after pouring with high-frequency mechanical vibrators operating at a minimum 4,500 impulses per minute. Apply vibration internally, externally, or a combination of both methods to flush the mortar to the surface of the forms. Vibrate succeeding concrete layers to extend into the previously placed layer. Use vibrators to thoroughly consolidate the concrete to a plastic mass without causing segregation. Do not permit vibrator heads to contact reinforcing steel, prestressing steel, or other embedded items to aid consolidation. Slowly insert and remove internal vibrators from the concrete.

Have one additional vibrator available at the site at all times during concrete pours.

C. Concreting in Adverse Weather Conditions. Perform concrete work meeting Subsections 552.03.9(A) and (B) when the ambient air temperature falls below 40 °F (4 °C), except that the placement temperature for steam-cured Class "Pre" concrete must be between 50 °F (10 °C) and 90 °F (32 °C) at placement.

When the ambient temperature before concrete is placed is 35 °F (2 °C) or less, pre-heat forms to a minimum 50 °F (10 °C) removing all frost, snow, and ice from the forms and components to be embedded in the concrete.

Do not permit the concrete temperature to exceed 90 °F (32°C).

Cover open buckets of concrete with wet burlap mats or other approved coverings, when necessary, to prevent slump loss or premature drying.

553.03.10 Curing

Water-cure prestressed concrete members meeting Subsection 551.03.6(A) or steam-cure as specified below.

Protect water-cured concrete meeting Subsection 552.03.9(C) requirements.

Perform elevated-temperature steam process cure meeting the following requirements.

Completely enclose or cover the casting beds for steam-cured members using curing blankets or other approved flexible coverings. Provide a minimum 6 inches (155 mm) of free air space between the enclosure or coverings and all concrete surfaces.

Secure flexible coverings to prevent moisture loss. Provide moisture before the cure cycle to aid hydration and prevent surface cracks caused by rapid water loss from the concrete.

Steam may be introduced before starting the cure cycle if the enclosure temperatures are maintained between 50 °F (10 °C) and 70 °F (21 °C). Fog-spray or cover the top surfaces of the members with wet blankets within 15 minutes after placing concrete to prevent moisture loss for a three hour period before the cure cycle.

Begin the steam-cure cycle after the concrete has been in place at least three hours. Maintain steam at 100 percent relative humidity, applied so it does not damage the surface of the concrete, forms, or tendons.

Raise the ambient temperature within the enclosures no faster than 40 °F (22 °C) per hour to a maximum temperature between 140 °F (60 °C) and 160 °F (71 °C). Maintain the temperature until the concrete has reached strength for transfer of prestress.

Once the cure cycle is complete, cool the beams by decreasing the temperature within the enclosures no faster than 40 °F (22 °C) per hour until the temperature difference between the inside and outside air is within 25 °F (14 °C), unless otherwise approved.

Keep a curing time-temperature record for each concrete pour in the casting bed. Provide one automatic temperature-recording thermometer for each 200 feet (61 m), or fraction thereof, of continuous bed length used. Record curing temperatures continuously for the full curing cycle. Place the temperature sensors at approved locations. Supplement automatic recording thermometers with standard bulb-type thermometers placed at approved locations. Certify the accuracy of automatic recorders once each year or when the recorder accuracy is in question. Steam curing is not permitted without automatic recorders.

The sideforms may be removed at the Contractor's discretion. Assume all responsibility removing forms before breaking the release cylinders. Concrete members damaged from early form removal will be rejected.

The cure cycle may be interrupted a maximum 20 minutes for form removal.

Do not expose the members to below-freezing temperatures within six days of casting. In place of the six-day requirement, the cure time may be based on the concrete strength. The concrete strength is determined by the average strengths of three standard 6-inch x 12-inch (152 mm x 305 mm) or 4-inch x 8-inch (102 mm x 203 mm) cylinders cast from different batches of concrete used in each round of beam castings. Expose these cylinders to the same cure and temperature conditions as the prestressed members. Immediately test the cylinders according to AASHTO T22 without further curing, once they are removed from the cure area.

Curing may be discontinued if the average strengths of the three cylinders equals or exceeds the strengths specified in Subsection 551.03.7(C)(2). Should all cylinders fail, protect the member from freezing temperatures for the 6-day period. Cool all members as specified in this Subsection.

Cast compression cylinders for field tests of the 28-day strengths following MT-101. Cast the number of test cylinders as required in Subsection 551.03.7(A)(2) and MT-111.

The Contractor may submit in writing, alternate curing methods, for approval.

553.03.11 Transfer of Prestress

Prestressed strands may be released when the concrete has:

1. Reached the minimum compressive strength for transfer of prestress;
2. The cure cycle is complete; and
3. Restrictive forms are removed.

If delays are anticipated, maintain the temperature in the curing enclosure at a minimum 50 °F (10 °C) until transfer of prestress.

Use positive, external hold-downs or weights to offset the uplifting forces in the member when the hold-down strands are released, when required.

Use a method of harped and straight strands release to hold the lateral eccentricity of prestress to a minimum. Detail the bed release and the strand-cutting pattern on the fabrication drawings. Changes to the release procedures shown on the approved drawings are not permitted except by written request and the Engineer's written approval.

Cast cylinders to determine prestressed transfer strengths using MT-101 and MT-111 as modified below:

- Cast and cure the release cylinders under the exact conditions the prestressed members were cured.
- The concrete sample for each cylinder will be selected at random from different batches.

Once the cure cycle is complete, test the release cylinders under AASHTO T 22. Test three cylinders to determine the prestressed transfer strengths for each round of beam castings. The average strengths of the three cylinders must equal or exceed:

F'r + 0.35S

Where:

S = the standard deviation of the strengths for the three cylinders
F'r = the required concrete transfer strength as specified in the contract

Test all three cylinders within 30 minutes.

Furnish the number of release cylinders required to perform these tests.

The Contractor may cast additional back-up test cylinders.

Should the release strengths not be reached and all back-up cylinders are broken, put the casting through at least one additional complete cure cycle. The Engineer may direct other tests to determine release strengths.

Test compression specimens using AASHTO T 22. While testing, apply the last one-half of the load at a rate between 1,200 to 3,000 psi (8.28 to 20.7 MPa) per minute.

The Inspector will witness the Fabricator's casting and testing of release cylinders.

553.03.12 Post-tensioning

Begin tensioning of the prestress reinforcing steel when the concrete cylinders representing the member to be prestressed reach the compressive strength shown on the approved fabrication drawings.

Stress the prestress reinforcing steel, using jacks, to the specified tension with the stress transferred to the end anchorage.

Measure the tension and elongation at all times.

Make a record of gauge pressures and elongation while post tensioning and submit it for review.

553.03.13 Bonding Steel

Bond post-tensioned steel to the concrete unless otherwise specified.

Clean all dirt, loose rust, grease, or other deleterious material from all pre-stress reinforcing steel.

Flush all conduits with water and blow them out with compressed air after post-tensioning.

Remove rubber sheaths used as enclosures, then flush and blow out the voids as described above.

Once cleaned, pressure-grout the conduit or void using a pressure not exceeding 100 psi (690 kPa). Continue grouting until a steady flow of grout exits from the pipe outlet. Close the outlet, then the inlet with the grout under pressure. Maintain the final grout pressure at between 50 psi to 100 psi (345 kPa to 690 kPa).

553.03.14 Concrete Surface Finish

Perform the concrete finish work immediately after de-tensioning. Give the exterior surfaces of exterior members and the entire bottom flange of all girders to the juncture with the beam web an ordinary finish as specified in Subsection 552.03.12(A).

All other beam surfaces may be left with the surface created by the forms, if the surfaces are true, even, and free of stone pockets, depressions, or surface projections. Point with mortar and strike off even with the surrounding surface, all air holes in the concrete measuring 1/2 inch (13 mm) or more in any direction. Repair rough, uneven, and non-uniform concrete surfaces using power grinders, carborundum stones, brushhammers, or other approved equipment and then apply an ordinary finish.

Match the appearance of the surface adjacent to the repair. Apply an ordinary finish to the entire adjoining surface of the member if a match is not possible.

Repair rock pockets identified for repair. Chip rock pockets back to sound concrete, clean, and permit inspection before patching. Rock pockets affecting the member's strength will be further evaluated before repair.

Notify the Inspector of all members having the prestress strand exposed for 8 inches (205 mm) or more on any one strand or any exposure of multiple strands before repair.

Provide an ordinary finish on beam ends not embedded in concrete. The Contractor may use approved epoxy or quick-setting grout products, provided the colors blend with the surrounding surface. Before finishing the beam ends, cut the strands back a minimum of 1/2 inch (13 mm) and fill the depressions with an approved epoxy.

When beam ends are to be embedded in concrete, the ends may be left rough and strands cut back to extend a maximum 1-inch (25 mm) beyond the surface of the concrete. Cut the strands in the area of the paving notch flush with the concrete surface.

Screed and rough-float the top surface of prestressed girders to the required depth of the member, bringing grout to the surface, and covering all aggregate.

Clean all projecting reinforcing stirrups of mortar and other foreign materials before starting the cure cycle.

553.03.15 Workmanship and Tolerances

All tolerances are applied to the theoretical positions and dimensions shown on the plans and approved fabrication drawings.

The tolerances from the plan and theoretical dimensions listed in Table 553-1 are the maximum acceptable cumulative deviations. The Engineer will verify that the girders are within the allowable tolerances when the girders alignment is not influenced by temporary temperature differences between the girders surfaces. Tolerances in other manufacturing sequences cannot accumulate to supersede any individual tolerance. Members having dimensions outside the tolerance limits may be rejected.

TABLE 553-1
TOLERANCES FOR PRESTRESSED CONCRETE MEMBERS

ELEMENT	TOLERANCE
Length of beam, end-to-end, measured at centerline of beam, top or bottom flange	± 3/4 inch (20 mm)
Centerline-to-centerline of end bearing plates	1/8 inch per 10 feet (3 mm per 3 m), but no greater than 1/2 inch (13 mm)
Depth of flanges, fillets, and web	± 1/4 inch (5 mm)
Depth overall	+ 1/2 inch (13 mm) to 1/4 inch (5 mm)
Width of flanges, fillets, and web	+ 3/8 inch (10 mm) to 1/4 inch (5 mm)
Beam ends - deviation from square or specified skew	Horizontal ± 1/4 inch (5 mm), Vertical 1/8 inch per foot (3 mm per 300 mm) of beam height or 1/2 inch (13 mm), whichever is less
Side insert, center-to-center and center to beam end	± 1/2 inch (13 mm)
Horizontal alignment (deviation from a straight line parallel to centerline of the member)	1/8 inch per 10 feet (3 mm per 3 m) of beam length but not greater than 1 inch (25 mm)
Camber differential between adjacent beams measured at release of prestress (to be applied only to identical members cast in same line)	1/8 inch per 10 feet (3 mm per 3 m) of span to a maximum of 1 inch (25 mm)
Stirrup bars (specified projection above beam top)	± 1/2 inch (13 mm)
Tendon position	± 1/4 inch (5 mm) in center of gravity of strand group and individual tendons
Position of deflection points for deflected strands	± 6 inch (150 mm)
Position of handling devices along centerline of beam	± 6 inch (150 mm)
Centerline of bearing plates to end of beam	± 1/4 inch (5 mm)
Bearing plates (deviation from a plane perpendicular to the vertical axis of the beam)	± 1/16 inch (2 mm)
Stirrup bars (longitudinal spacing)	± 1 inch (25 mm)
Position of post-tensioning ducts	± 1/4 inch (5 mm)

553.03.16 Storage and Transportation

Exercise care during transporting, storing, hoisting, and handling of the precast units to prevent cracking or damage.

Transport precast girders and slabs in an upright position, with the points of support and directions of the reactions with respect to the members being approximately the same during transport and storage as when the members are in the final planned position.

Lift the beams using the lifting eyes. During lifts, use spreaders between slings to eliminate the horizontal component of the lifting force from being applied to the beam. A spreader is not required when the angle between the sling and the top of the beam exceeds 45 degrees.

Do not move prestressed members from the casting yard until the concrete has reached the 28 day strength and the Project Manager has been notified of the intent to transport the beams.

Replace units damaged by improper storing, handling, or transporting at Contractor expense.

553.03.17 Placing

Place precast, prestressed structural members as specified. Place piling under in Section 559.

553.04 METHOD OF MEASUREMENT

Precast, prestressed concrete members, excluding piling, are measured by the foot (meter) to the nearest 0.1 foot (0.1 m) for each specified type and/or size, installed and accepted.

Prestress beams are measured by the foot (meter) from centerline bearing to centerline bearing to the nearest 0.1 foot (0.1 m).

553.05 BASIS OF PAYMENT

Payment for the completed and accepted quantities is made under the following:

Pay Item	Pay Unit
Precast Member	Foot (meter)
Prestress Member	Foot (meter)
Concrete Piling	See Subsection 559.05

Payment at the contract unit price is full compensation for all necessary resources to complete the item of work under the contract.

SECTION 554
PRECAST CONCRETE PRODUCTS

554.01 DESCRIPTION

This work is the furnishing and installing of reinforced precast concrete bridge members, precast curbs, barrier rails, cattle guard bases, guardrail posts, and other precast concrete products.

554.02 MATERIALS

554.02.1 Concrete

Furnish portland cement concrete meeting Section 551 requirements.

554.02.2 Reinforcing Steel

Furnish reinforcing steel meeting Section 555 and Subsection 711.01 requirements.

554.02.3 Structural Steel

Furnish Structural steel meeting Subsection 711.02 requirements.

554.03 CONSTRUCTION REQUIREMENTS

554.03.1 Fabrication Drawings

Submit fabrication drawings and design calculations for review. Do not begin fabrication until the drawings are returned. The drawings must include the following information:

1. An erection layout with each individual piece identified;
2. The concrete mix design proposed for use in production including proposed admixtures;
3. The size, type, capacity, and location of items incorporated in the member such as chairs, inserts, and other hardware; and
4. All other information necessary to fabricate and install the product.

Submit prints of the drawings and calculations initially. After review furnish additional prints of drawings. Furnish prints on 22-inch x 36-inch (A1) paper with a 1 1/2-inch (46 mm) margin on the left side and 1/2-inch (43 mm) margins on the other three sides.

554.03.2 Design of Concrete Mixtures

Upon request, the Engineer will furnish a concrete mix design when a specific concrete class is specified. The Contractor may submit a proposed mix design for approval, in lieu of using the Department-furnished mix design, when concrete is designated by class.

Submit a proposed mix design with the shop drawings for approval.

The Contractor may request to change aggregate size and gradation to use aggregates in an established plant. Submit the request in writing and include sizes and gradation limits for each size aggregate. Furnish evidence of satisfactory performance of concrete produced from the aggregates. Do not make changes in the aggregates without approval.

554.03.3 Sampling, Handling, Batching, and Mixing

Sample, handle, batch, and mix materials for concrete under Subsection 551.03.3.

554.03.4 Forms and Forming

Meet the form requirements in Subsection 552.03.4.

554.03.5 Placing Concrete

Place concrete under Subsection 552.03.5.

554.03.6 Curing and Testing Concrete

Cure precast concrete products by water curing, impervious membrane curing, elevated temperature curing, or a combination of these methods.

Perform water curing and impervious membrane curing meeting Subsection 551.03.6 requirements.

Perform elevated-temperature steam process curing meeting Subsection 553.03.10 requirements.

Submit procedures for curing by the elevated-temperature electric coil process or a combination of methods in writing for approval before use.

Perform at least one test per 50 cubic yards (35 cubic meters) or per each day's production if less than 50 cubic yards (35 cubic meters) to verify reaching the compressive strength required to discontinue curing.

A test is the average strengths of three cylinders, each cast from different batches of concrete used in the day's production. Take the three samples from as many different batches as possible if more than two batches are used.

Sample and cast cylinders using MT-101.

Cure until the compressive strength of the standard 6-inch x 12-inch (152 mm x 305 mm) or 4-inch x 8-inch (102 mm x 203 mm) cylinders, cured under the same conditions as the concrete represented, reaches the required strength for the class of concrete or the specified strength.

Field-cure cylinders a maximum 28 days and test for compressive strength within 24 hours after removal from the field curing conditions. Perform strength testing under AASHTO T 22. Furnish the certified laboratory test results or arrange for the tests to be witnessed the Department.

Test results are acceptable if the average of the three cylinder strengths exceed the strength for the concrete class or the specified strength and no individual cylinder tested has a strength less than 90 percent of the specified strength.

Continue un-interrupted curing until test results are obtained. Should all cylinders be tested without reaching the specified strength, the concrete represented by the cylinders may be rejected.

554.03.7 Cold-weather Concreting

Furnish concrete at between 60 °F to 90 °F (15 °C to 32 °C) for placing when the air temperature is less than 40 °F (4 °C). Heat the concrete under Subsection 552.03.9(B).

Clear form work of snow, ice, and frost before placing concrete.

Protect the concrete from freezing for at least 48 hours after its placed or until it reaches the strength required to discontinue curing.

After 48 hours, provide freeze protection to develop the required strength.

Construct and protect bridge components meeting Subsection 552.03.9(C) requirements.

Assume all risk of concrete work during cold weather.

554.03.8 Form Removal

Remove lateral support forms only when it does not damage the concrete. Do not interrupt curing and protection in excess of 30 minutes for form removal.

554.03.9 Finish on Exposed Surfaces

Produce concrete surfaces free from rock pockets, depressions, or projections.

Scattered holes from surface trapped air are not considered defects. Point holes larger than 1/2 inch (13 mm) in any direction with mortar and strike off even with the surface. Apply an ordinary finish to surfaces not smooth and uniform in texture and appearance under Subsection 552.03.12.

554.03.10 Handling, Transporting, and Storage

Do not remove, handle, or transport items designed to carry loads from the casting bed before they reach the required strength.

Other items may be moved from the casting bed to other curing locations when they have reached the strength to prevent damage.

Replace all cracked or broken items at Contractor expense.

Handle, transport, and store precast concrete items without damage. Replace or repair all damaged items at Contractor expense.

554.03.11 Placement

Place precast concrete members as specified.

554.04 METHOD OF MEASUREMENT

554.04.1 Precast Concrete Curb

Precast concrete curb is measured under Subsection 609.04.

554.04.2 Precast Concrete Barrier Rail

Precast concrete barrier rail is measured under Subsection 606.04.

554.04.3 Plain Reinforced Precast Concrete Bridge Members

Plain reinforced precast concrete bridge members are measured under Subsection 553.04.

554.04.4 Precast Concrete Cattle Guard Bases

Precast concrete cattle guard bases are not measured or paid for separately but are included in the payment for cattle guards under Subsection 611.05.

554.04.5 Precast Concrete Guardrail Posts

Precast concrete guardrail posts are not measured or paid for separately but are included in the payment for metal guardrail under Subsection 606.05.

554.04.6 Other Precast Concrete Products

Other specified precast concrete products are measured and paid for as specified in the contract.

554.05 BASIS OF PAYMENT

Payment for the completed and accepted quantities is made under the following:

Pay Item	Pay Unit
Precast Concrete Curb	See Subsection 609.05
Precast Concrete Median Barrier Rail	See Subsection 606.05
Precast Concrete Bridge Members	See Subsection 553.05

Payment at the contract unit price is full compensation for all necessary resources to complete the item of work under the contract.

SECTION 555
REINFORCING STEEL

555.01 DESCRIPTION

This work is furnishing and placing reinforcing steel and wire fabric.

555.02 MATERIALS

Furnish materials meeting the following Subsection requirements:

Reinforcing Steel 711.01.1
Epoxy-coated Reinforcing Bars 711.01.2
Wire and Wire mesh 711.01.3

555.03 CONSTRUCTION REQUIREMENTS

555.03.1 Protection of Material

Protect reinforcing steel from damage. Store reinforcing and supports on blocks.

Handle epoxy-coated steel reinforcing with padded or nonmetallic slings and padded straps to prevent damage to the epoxy coating. Store the bars on wooden cribs. Damaged material will be rejected, or repaired meeting AASHTO M 284 at Contractor expense.

Cover all reinforcing steel from weather exposure using an opaque moisture resistant covering that permits air circulation. Do not permit epoxy coated reinforcing steel to be exposed to sunlight in excess of 60 days.

555.03.2 Fabrication

Bend reinforcing bar as specified in the contract.

Bend all bars cold. Do not field bend bars partially imbedded in concrete unless otherwise specified.

Meet Table 555-1 bend radii for standard hooks and all other bars other than stirrups and ties. Provide a minimum inside radii of two bar diameters for stirrups and ties.

TABLE 555-1
MINIMUM BENDING RADII

BAR SIZE	MINIMUM INSIDE RADII
3 thru 8 (#10 thru #25)	3 bar diameters
9 thru 11 (#30 thru #35)	4 bar diameters
14 or 18 (#45 or #55)	5 bar diameters

Obtain approval for special fabrication or bends exceeding 90 degrees for No's. 14S and 18S reinforcing steel.

Ship reinforcing bar in bundles tagged and marked meeting the Concrete Reinforcement Steel Institute Code of Standard Practice.

Submit fabrication drawings when specified or requested.

555.03.3 Placing and Fastening

Place the reinforcing steel as shown in the contract and hold in place during concrete work. Submit a written request for approval to weld reinforcing steel to hold in place or fasten. Include in the request ANSI/AWS procedures to be used.

Assure steel reinforcing is free of loose rust and scale, dirt, paint, oil, or other foreign material.

Verify the anchor bolt clearances before placing reinforcing steel.

Tie bars at all intersections unless bar spacing is less than 1 foot (305 mm) in each direction, which requires alternate intersections be tied.

Provide the minimum cover for reinforcing bars shown in Table 555-2.

TABLE 555-2

MINIMUM BAR EMBEDMENT

BAR LOCATION	EMBEDMENT
Top of Slab	2 3/8 inches (60 mm)
Bottom of Slab	1 inch (25 mm)
Stirrups and Ties	1 1/2 inches (38 mm)
Footing and Pier Shafts	3 inches (75 mm)

Separate forms using stays, ties, hangers, metal chairs, blocks, or other approved supports.

Precast mortar blocks may be used at locations approved by the Project Manager, excluding supports for bridge deck slab reinforcing steel. Use blocks precast from concrete used on the project and water cured for seven days before use. Use blocks of the size specified having an embedded wire for fastening to the reinforcing bar. Separate bar layers using precast mortar blocks, upper continuous metal chairs, or other approved devices.

Separate the upper and lower mats of reinforcing steel for deck slabs, depending upon the vertical distance between the mats, using "Upper Continuous High Chair (U.C.H.C.)" or "Slab Bolsters with Runners (S.B.R.)". Place Continuous bar supports at right angles to structure centerline for "Flat Slab" structures and parallel to structure centerline for all other deck slabs. Do not use pebbles, pieces of broken stone, concrete rubble, broken brick or building blocks, metal pipe, or wooden blocks.

Use metal chairs and supports contacting epoxy-coated bars that are epoxy coated or coated with another inert approved coating.

Use plastic-coated tie wires to tie the coated bars in place.

Space deck slab reinforcing supports a maximum 4 feet (1,200 mm). Space supports closer if necessary to prevent deflection during placement of concrete.

Obtain approval of reinforcing placement before placing concrete. Remove concrete placed before inspection.

Flatten rolled reinforcing fabric into sheets before placing.

555.03.4 Splicing

Furnish all reinforcing steel in the specified lengths. Splice as shown in the contract or as directed.

555.03.5 Reinforcing Steel - Material Guaranty and Random Sampling

Furnish for each shipment of reinforcing steel delivered to the project, duplicate copies of the following:

1. Shipping invoice showing the weight and price per pound (kilogram) of all of the steel in the shipment;
2. Certified mill test reports showing physical and chemical analysis on each heat of reinforcing steel;
3. A statement from the fabricator certifying that the mill tests furnished are representative of the reinforcing steel furnished and that it meets Subsection 106.09 requirements; and
4. For epoxy-coated reinforcing bars, the coating applicator must furnish with each shipment a certificate of compliance confirming that the coated reinforcing bars were cleaned,

coated, and tested meeting the requirements of AASHTO M 284 and Subsection 106.09. Additionally, the certification must include for each bar size the preheat temperatures, cure times, thickness checks, holidays detected, and bend test results.

A shipment is the quantity of reinforcing steel in each truckload delivered to the project. When delivery is by railroad car, each 20 tons (18.1 mt), or fraction thereof, is a shipment.

Furnish the samples as requested for testing.

Do not place concrete until the steel test results are known. If a reinforcing steel sample fails, two additional samples representing the failed sample will be tested. If either of the check samples fail, the steel in the shipment represented by the failing sample may be rejected; or if the Project Manager determines that the steel is usable, a price reduction will be assessed as follows:

P = A x B

Where:

A = Total invoice price of reinforcing steel in the lot[1]

B = 10 percent, 20 percent, or 30 percent, dependent upon departure from specifications; the value to be used will be determined by the Engineer

P = Price reduction for the lot

Notes:

1. A lot is defined as all the bars of one bar number and pattern of deformation contained in an individual shipment.

The amount of reduction calculated above will be deducted from monies due the Contractor on the final estimate.

Remove and replace all rejected steel at Contractor expense. Furnish invoice statements, mill reports, and fabrication certificates for replacement steel. Replacement steel is subject to the tests specified above.

No reinforcing steel in a shipment will be final accepted until the test results are known. The Contractor may proceed with the work at its own risk before testing.

555.04 METHOD OF MEASUREMENT

The reinforcing steel quantity in the contract is the calculated theoretical weight of the steel in pounds (kilograms), measured as shown in the contract or ordered in writing, complete in place and accepted.

Plan quantities will not be re-measured except as provided for in Subsection 555.05.

The weights of standard sizes of reinforcing bars meeting the requirements of AASHTO M 31 are computed using Table 555-3.

TABLE 555-3
WEIGHTS OF STANDARD SIZES OF REINFORCING BARS

Bar Size English (metric)	Bar Diameter inch (mm)	Weight lb/ft (kg/m)
No. 3 (#10)	0.375 (9.5)	0.376 (0.560)
No. 4 (#13)	0.500 (12.7)	0.668 (0.994)
No. 5 (#16)	0.625 (15.9)	1.043 (1.552)
No. 6 (#19)	0.750 (19.1)	1.502 (2.235)
No. 7 (#22)	0.875 (22.2)	2.044 (3.042)
No. 8 (#25)	1.000 (25.4)	2.670 (3.973)
No. 9 (#29)	1.128 (28.7)	3.400 (5.060)
No. 10 (#32)	1.270 (32.3)	4.303 (6.404)
No. 11 (#36)	1.410 (35.8)	5.313 (7.907)
No. 14 (#43)	1.693 (43.0)	7.650 (11.38)
No. 18 (#57)	2.257 (57.3)	13.600 (20.24)

Non-standard reinforcing bars or wire fabric, when required, have the unit weight specified in the contract.

No allowance is made for clips, wires, separators, or other material used for fastening or supporting the reinforcing steel.

555.05 BASIS OF PAYMENT

Payment for the completed and accepted quantities is made under the following:

Pay Item	Pay Unit
Reinforcing Steel	Pound (kilogram)

Reinforcing steel is paid in place for the quantities shown in the contract, except as follows:

1. The calculated quantities involved in changes ordered in writing by the Engineer are added or deducted from the plan quantities.
2. A recalculation will be made and the corrected quantity will be included for payment, in lieu of the plan quantity, when the plan quantity of reinforcing steel in any complete structure is in error by five percent or more. A complete structure is the smallest portion of a total structure for which a quantity is included in the contract. The party to the contract requesting an adjustment must present to the other party three copies of the description, location and recalculated quantities of the structure having the quantity error.

Partial payments for reinforcing steel will be made based on the contract quantity as follows:

1. 85 percent when the material is accepted and placed and tied.
2. 100 percent when covered with concrete.

SECTION 556
STEEL STRUCTURES

556.01 DESCRIPTION

This work is the furnishing, fabricating, painting, and erecting of steel structures and the steel structure portions of composite structures.

The Department has calculated the contract quantities using the following:

Material	Weight Per Cubic Foot (cubic meter)
Malleable Iron	470 lbs (7,530 kg)
Wrought Iron	487 lbs (7,800 kg)
Rolled, Cast Copper Bearing, Silicon, Nickel, and Stainless Steel	490 lbs (7,850 kg)

The weights of rolled shapes and plates up to and including 36 inches (915 mm) in width are computed based on their nominal weights and dimensions as shown on the shop drawings. One-half of the allowed percentage of overrun in weight as tabulated in ASTM A 6 will be added to the nominal weights of plates exceeding 36 inches (915 mm) in width. The weight is computed on the basis of rectangular dimensions for all plates and overall lengths for all structural shapes with no deductions for copes, slips, sheared edges, punching, borings, milling, or planing. When parts can be economically cut in multiples from materials of larger dimension, the calculated weight is that of the material from which the parts are cut.

Bolts, nuts, and washer weights are the calculated weight in the AISC Manual of Steel Construction.

A 0.4 percent multiplier may be specified in the contract and added to the computed weight of metals for shop paint.

Weld metal weight is not computed.

556.02 MATERIALS

Furnish materials meeting the following Subsection requirements:

Structural Steel 711.02
Structural Steel Tubing 711.03
Pins and Rollers.....711.04
Welding Electrodes.....711.05
High Tensile Strength Bolts 711.06
Bolts and Nuts 711.07
Galvanized Metal 711.08
Welded Stud Shear Connectors 711.09
Castings.....711.12
Fiber-reinforced Pads for Bearing Plates.....711.16
Bearing Assembly Anchor Bolts for Bridges 711.13
Elastomeric Bearing Devices.....711.14
Compression Joint Seals 711.15

556.03 CONSTRUCTION REQUIREMENTS

556.03.1 Pre-qualification

Use metal fabricators that are pre-qualified under the AISC Quality Certification Program. Registration and certification of the plant or shop under the AISC Quality Certification Program (categories seen below) and submission of a valid certificate to the Bridge Engineer, MDT, PO

Box 201001, Helena, MT 59620-1001 is required. Furnish an annual endorsed copy for continued qualification.

AISC has quality certification in the following categories:

A. Conventional Steel Building Structures (SBD). The certification is typically specified for small public service and institutional buildings (schools, etc.), shopping centers, light manufacturing plants, miscellaneous and ornamental iron work, warehouses, low rise beam/column/light truss structures.

B. Simple Steel Bridge Structures (SBR). The certification is typically specified for unspliced rolled beam bridges.

C. Complex Steel Building Structures (CBD). The certification is typically specified for high-rise buildings, large public service and institutional buildings, heavy manufacturing plants, powerhouses, and petro/chemical processing facilities.

D. Major Steel Bridges (CBR). The certification is typically specified for large span bridges. Main members are typically fabricated girders that must be spliced with a welded or bolted connection.

E. Metal Building Systems (MB). Pre-engineered metal building systems including cold formed members and panels.

Fabricators certified for Complex Steel Building Structures are automatically certified for Conventional Steel Building structures and those certified for Major Steel Bridges are automatically certified for Simple Steel Bridge Structures.

A. Sophisticated Paint System Endorsements (P1, P2, P3). There are three Paint Endorsements available:

1. **P1.** Sophisticated Paint Endorsement - Enclosed;
2. **P2.** Sophisticated Paint Endorsement - Covered; and
3. **P3.** Sophisticated Paint Endorsement - Exposed

B. Fracture Critical Members Endorsement (F). Familiarity with procedures required to produce fracture critical members in accordance with a fracture control plan as defined by AASHTO or AREA.

Use only fabricators having a Category CBR certification to fabricate the following:

A. Fracture critical members and attachments. Fabricators must have the Fracture Critical Endorsement (F);

B. Main members, except for rolled beams;

C. Welded floor beams; and

D. Cross frames and diaphragms for curved bridges.

Use fabricators having a Category SBR, SBD, CBD, or CBR certification to fabricate the following:

A. Modular expansion joints;

B. Welded bearings;

C. Steel grid flooring;

D. Overhead, truss, and cantilever sign structures; and

E. Lighting poles and anchor bases.

556.03.2 Fabrication Drawings

Submit the fabrication drawings for review. Include on the drawings complete details, dimensions, size of material, welding procedures, and other information necessary for the complete fabrication and erection of the work.

Check and approve fabrication drawings before submitting. The Contractor's approval stamp and signature must be on each drawing.

The Project Manager must review the Drawings before fabrication begins. The Department has 20 working days to review and return the fabrication drawings. The contract time will be extended day for day for any delay beyond the 20-day review period if the Department's delay affects the Contractor's operation as shown on the current work schedule.

Furnish all fabrication drawings on 22-inch x 36-inch (A1 paper) with a 1 1/2-inch (46 mm) margin on the left side and a 1/2-inch (43 mm) margin on the other three sides. Once the work is completed, provide the original tracings, if required, to the Project Manager.

Changes to the plans or substitutions of sections requested by the Contractor regarding plate size, splice location, details of appurtenances, or details of welds cannot decrease the dimensions or section properties of the member or increase the weight of the member.

Submit all requests for changes for review and approval. All approved changes are at the Contractor's expense, including any additional freight and handling charges. The approved changes will be by change order, and include any cost savings.

556.03.3 Mill and Shop Inspection

A. **Inspection of Work.** Do not begin manufacturing or shop fabrication until the Department's Inspector has inspected the shop.
B. **Facilities for Inspection.** Furnish facilities for inspecting the material and workmanship in the mill and shop. Allow the Inspector free access to the work at all times.
C. **Inspector's Authority.** The Inspector may reject material or work not meeting the specifications. In case of dispute, the Contractor may appeal the Inspector's decision to the Project Manager.
D. **Mill Test Reports.** Furnish the Project Manager a complete certified mill test report showing chemical analysis and physical tests for each heat of steel for all members. Identify each piece of steel with a mark number on the mill test report.
E. **Facilities for Testing.** Furnish, at Contractor expense, test specimens, labor, testing machines, and tools to make the specimens and tests.
F. **Rejections.** Material or finished members accepted by the Inspector may be rejected if the material is subsequently found defective. Replace or repair rejected material at Contractor expense.

556.03.4 Storage and Identification of Materials

Store structural steel meeting Subsection 556.03.17 requirements.

Mark alloy and high-strength steels as required by Article 11.4.1 of the AASHTO Standard Specifications for Highway Bridges. Mark material required to meet a Charpy requirement for identification.

556.03.5 Workmanship and Finish

Round all edges of primary members corners to a 1/16-inch (2 mm) radius.

Make all surfaces and edges smooth, uniform, and free from fins, tears, and cracks.

Shear, flame cut, and chip neatly and accurately. Neatly finish all exposed portions of the work.

Straighten rolled material before lay out or working. Do not injure the metal when straightening. The maximum temperature of the steel cannot exceed 1000 °F (537 °C) unless approved. Perform heat straightening of AASHTO M 270 Gr. 100/100w (ASTM A 709 Gr 100/100w) or ASTM A 517 steel only under controlled procedures with the heat application approved by the Project Manager. Material with sharp kinks and bends will be rejected.

Lay out and cut plates and splice plates for flanges and webs with the direction of rolling parallel to the longitudinal axis of the girder. Show on the shop drawings the direction of rolling for these plates.

Curve rolled beams and welded girders meeting Articles 11.4.12.2 and 11.4.7 of the AASHTO Standard Specifications for Highway Bridges.

556.03.6 Finishing and Shaping

Finish members true to line, free from twists, bends, and open joints. Camber girders as shown on the plans.

A. Edge Planing. Plane sheared plate edges exceeding 5/8-inch (16 mm) in thickness and carrying stress to 1/4-inch (5 mm). Fillet re-entrant cuts before cutting.

B. Facing of Bearing Surfaces. For bearing, base plates and other bearing surfaces in contact with other members or with concrete, meet the surface-roughness requirements of Table 556-1.

TABLE 556-1

SURFACE ROUGHNESS REQUIREMENTS[1]

ITEM	REQUIREMENT
Steel slabs	ANSI 2,000 (50 µm)
Heavy plates in contact in shoes to be welded	ANSI 1,000 (25 µm)
Milled ends of compression members, stiffeners, & fillers	AMS 500 (12.5µm)
Bridge rollers and rockers	ANSI 250 (6.3 µm)
Pins and pin holes	ANSI 125 (3.2 µm)
Sliding bearings	ANSI 125 (3.2 µm)

Notes:

1. As defined in ANSI B Y 14.36 - 1978 Surface Roughness, Waviness, and Lay, Part I

Stress relieve shoes meeting AWS specifications after all welding and before pin holes are drilled or curved bearing surfaces are finished.

C. Abutting Joints. Face and bring to an even bearing, abutting joints in compression members, girder flanges, and tension members, if specified. Joints not faced must have an opening not exceeding 1/4-inch (5 mm).

D. End Connection Angles. Build floor beams, stringers, and girders with end connection angles to exact length back-to-back of connection angles. Assure the finished thickness of the angles is at least that shown on the plans if end connections are faced.

E. Web Plates. Do not exceed a 3/8-inch (10 mm) clearance at web splices between the ends of the web plates. Do not exceed 1/4-inch (5 mm) clearance at the top and bottom ends of the web splice plates.

F. Bent Plates. Furnish cold-bent, load-carrying, rolled-steel plates meeting the following requirements:

1. Use stock plates that place the bend lines at right angles to the direction of rolling; and

2. Bending must not crack the plate. Meet minimum bending radii, measured to the concave face of the metal, as specified in Table 556-2.

TABLE 556-2

MINIMUM BENDING RADII - ROLLED STEEL PLATES

THICKNESS OF PLATE IN INCHES (mm)					
	Up to 1/2 (12)	Over 1/2 to 1 (12 to 25)	Over 1 to 1 1/2 (25 to 38)	Over 1 1/2 to 2 1/2 (38 to 63.5)	Over 2 1/2 to 4 (66 to100)
Bending Radii[2]	2t[1]	2 1/2 t[1]	3t[1]	3 1/2 t[1]	4t[1]

Notes:

1. t = plate thickness
2. For all grades of structural steel in this specification.

Hot bend low alloy steel over 1/2-inch (12 mm) thick for small radii if required.

Springback allowance for AASHTO M 270 Gr. 100/100w (ASTM A 709 Grade 100/100w) and ASTM A 517 steels is about 3 times that for structural carbon steel. When break press forming, use a lower die span at least 16 times the plate thickness.

Hot bend the plates at a temperature not exceeding 1,200 °F (649 °C), excluding AASHTO M 270 Grade 100/100w (ASTM A 709 Grade 100/100w) and ASTM A 517 steels if a shorter radius is required. Re-quench the plates and temper following the mill's common practice if AASHTO M 270 Grade 100/100w (ASTM A 709 Grade 100/100w) or ASTM A 517 steel plates to be bent are heated to a temperature exceeding 1,125 °F (607 °C). Hot bent plates must meet requirement (1) above.

3. Round the corners of the plate to a radius of 1/16-inch (2 mm) throughout the area to be bent.

G. Fit of Stiffeners. Mill or grind end stiffener plates or girder and stiffener angles for use as supports for concentrated loads to provide an even bearing against the flange. Make fillers under stiffeners to fit within 1/4-inch (5 mm) at each end. Welding is permitted in lieu of milling or grinding if noted in the contract. Welding transversely across the tension flanges of beams or girders is permitted only with the Project Manager's approval. Horizontal stiffeners must not leave a gap exceeding 2 inches (50 mm) between the vertical stiffeners and the end of the horizontal stiffeners.

H. Flame Cutting. Steel or wrought iron may be flame cut, if a smooth surface is produced using a mechanical guide. Perform hand flame cutting only where approved, smoothing the surface by planing, chipping, or grinding. Adjust the cutting flame to prevent cutting beyond the specified lines. Make fillet re-entrant cuts having a minimum radius of 1/2 inch (10 mm).

Remove flame-cut edges back at least 1/4-inch (5 mm) by milling, chipping, or grinding for silicon steel. Machine flame-cut edges may be used as cut if the edges are softened after cutting by either of the following methods:

1. Heat the cut edge uniformly and progressively to a red heat (1,150 °F to 1,250 °F) (621 °C to 676 °C) to at least 1/16-inch (2 mm) deep; or

2. Using a post-heating torch attached to and following the cutting torch; regulate the tips, gas pressure, speed of travel, and the distance of post-heating torch from kerf to the thickness of the steel.

556.03.7 Pins and Rollers

A. General. Furnish straight, smooth pins and rollers meeting the specified dimensions, free from flaws. Forge and anneal pins and rollers more than 9 inches (225 mm) in diameter. Pins and rollers 9 inches (225 mm) in diameter or less may be forged and annealed or cold-finished carbon-steel shaft.

Gradually cool pins 9 inches (225 mm) in diameter or larger to prevent damage before annealing. Bore a hole 2 inches (50 mm) or larger in diameter the full length along the axis.

B. Boring Pin Holes. Bore pin holes to the specified diameter at right angles with the axis of the member, and parallel with each other unless otherwise specified. Finish cut the final surface.

Maintain a tolerance of ± 1/32-inch (1 mm) for outside-to-outside of end holes in tension members and inside-to-inside of end holes in compression members.

Bore holes in built-up members after the welding is completed.

C. Pin Clearances. Meet the following pin hole diameter maximum tolerances:

1. The pin diameter plus 0.02-inch (0.5 mm) for pins 5 inches (125 mm) or less in diameter.

2. 1/32-inch (1 mm) for larger pins.

D. Surface Finish. Finish surfaces of bridge rollers, rockers, pins and pin holes meeting Subsection 556.03.6(B) requirements.

E. Pilot and Driving Nuts. Furnish two pilot nuts and two driving nuts for each size of pin unless otherwise specified. Pilot and driving nuts are not required when shoes are assembled at the fabrication plant.

F. Threads. Use Unified Standard Series UNC - ANSI B1.1, Class 2A threads for external threads, and Class 2B for internal threads, for all imperial dimension bolts and pins for structural steel construction, except for pin end diameters of 1 3/8 inches (35 mm) or more which must be 6 threads per inch (25 mm).

Furnish American Standard Metric Screw Treads - M Profile, ANSI B1.13M-1983 for all metric dimension bolts and pins for structural steel construction. Tolerance is Class 6H/6g. Use a 4 mm pitch for pin end diameters of 1 3/8 inches (35 mm) or more.

556.03.8 Bolt Holes

A. General. Punch or drill all bolts holes.

Members built up with five thicknesses or less of metal may be punched 1/16-inch (2 mm) larger than the nominal diameter of the bolt, if the metal thickness does not exceed 3/4-inch (19 mm) for carbon steel or 5/8-inch (16 mm) for alloy steel.

Sub-punch or sub-drill all holes 3/16-inch (5 mm) or smaller for members exceeding 5 thicknesses, where the material is 3/4-inch (19 mm) carbon steel or thicker, or 5/8-inch (16 mm) in alloy steel. Ream the holes 1/16-inch (2 mm) larger. The holes may be drilled from the solid to 1/16-inch (2 mm) larger than the nominal diameter or the bolts.

B. Punched Holes. Make holes, punched full size, 1/16-inch (2 mm) larger than the nominal diameter of the bolt. The die diameter cannot exceed the diameter of the punch by more than 1/16-inch (2 mm).

Ream undersized holes. Clean-cut holes without torn or ragged edges. Poorly matched holes will be rejected.

C. Accuracy of Punched and Sub-drilled Holes. Punch all holes, punched full size, sub-punched, or sub-drilled so that after assembling (before any reaming is done) a cylindrical pin 1/8-inch (3 mm) smaller in diameter than the nominal size of the punched hole will enter without drifting, in at least 75 percent of the contiguous holes in the same

plane. Any hole that will not pass a pin 3/16-inch (5 mm) smaller in diameter than the nominal size of the punched hole will be rejected.

D. Reamed or Drilled Holes. Ream or drill all holes, perpendicular to the member, and not to exceed 1/16-inch (2 mm) larger than the nominal diameter of the bolts. Where practical, use mechanically directed reamers.

Drill holes 1/16-inch (2 mm) larger than the nominal diameter of the bolts.

Remove all outside surface burrs. Poorly matched holes will be rejected. Use twist drills for reaming and drilling. Disassemble assembled parts to remove burrs caused by drilling. Assemble connecting parts to be reamed or drilled and held during the work, then match-mark before disassembling.

E. Accuracy of Reamed or Drilled Holes. Eighty-five percent of reamed or drilled holes in any contiguous group must not exceed a 1/32 inch (0.8 mm) offset between adjacent thicknesses of metal.

556.03.9 Bolts and Bolted Connections

A. General. Make bolted connections meeting the contract requirements. Use unfinished bolts (ordinary rough or machine bolts). Provide turned bolts when specified. Special ribbed drive-fit bolts may be substituted for turned bolts with the Project Manager's written approval.

Provide bolted connections, using high-tensile-strength bolts, meeting Subsection 556.03.9(E) requirements.

Furnish bolts that are free of rust. Lubricate bolts before use.

Drive the bolts into the holes without damaging the thread. Use snaps to prevent damaging the heads.

Draw the heads and nuts tightly against the work with wrenches. Tap bolt heads with a hammer as the nuts are being tightened.

Use beveled washers to provide full bearing to the head or nut where bolts are used on beveled surfaces.

All bolts threads must be cut and finished.

Fully draw up the nuts of unfinished turned bolts and ribbed bolts after tightening.

Fully erect continuously supported girder sections between expansion joints before production bolt tightening. Tighten field splices to the proof loads in Table 556-5 after field splices have been set to grade.

B. Unfinished Bolts. Furnish standard unfinished bolts having hexagonal heads; with nuts having a bolt hole diameter 1/16-inch (2 mm) larger than the bolt diameter. Use threaded bolts, for transferring shear, to prevent no more than one thread within the grip of the metal. Furnish bolts that extend through the nuts a maximum 1/4-inch (6 mm).

C. Turned Bolts. Ream turned bolt holes, and turn the bolts to a driving fit with the threads entirely outside of the holes. Use hexagonal headed bolts and nuts and provide washers. Turned bolts must be finished cut.

D. Spacing and Edge Distance of Bolts. Follow the spacing and edge distance of bolts specified in Table 556-3.

TABLE 556-3
SPACING AND EDGE DISTANCE OF BOLTS

BOLT LOCATION	BOLT SIZE			
	1 inch (M24)	7/8 inch (M22)	3/4 inch (M20)	5/8 inch (M16)
	Spacing or Distance, inches (mm)			
Minimum spacing of bolts, center-to-center	3 1/2 (90)	3 (75)	2 1/2 (65)	2 1/4 (55)
Minimum distance from center of bolt to nearest sheared edge and to edges of beams and channels	1 3/4 (42)	1 1/2 (38)	1 1/4 (34)	1 1/8 (28)
Minimum distance from center of bolt to nearest rolled, planed edge, or gas cut	1 1/2 (30)	1 1/4 (28)	1 1/8 (26)	1 (22)
Maximum distance from center of bolt to nearest edge	Eight times the thickness of the thinnest outside plate but not greater than 5 (125) for all bolt sizes			

E. Bolted Connections - High-Tensile-Strength Bolts.

1. Bolt Lengths. Use bolt lengths having the grip-length values in Table 556-4 plus the total thickness of connected material. The values in Table 556-4 consider nut, one flat washer, and bolt point.

Adjust the length to the next 1/4-inch (10 mm) increment up to a 5-inch (120 mm) bolt and to the next 1/2-inch (10 mm) increment for bolts over 5 inches (120 mm).

Increase the bolt length 1/8 inch (3.2 mm) if direct tension indicator washers are used.

TABLE 556-4
BOLT LENGTH DETERMINATION

BOLT DIAMETER Inches (mm)	ADDED GRIP LENGTH[1] inches (mm)
1/2 (13)	7/8 (22)
5/8 (16)	1 (25)
3/4 (19)	1 1/8 (29)
7/8 (22)	1 3/8 (35)
1 (25)	1 1/2 (38)
1 1/8 (29)	1 5/8 (41)
1 1/4 (32)	1 3/4 (44)
METRIC	
M16	25 mm
M20	30 mm
M22	35 mm
M24	40 mm

Notes:
1. Add to total thickness of connected material.

Where beveled washers are used, adjust bolt lengths to account for the use of nonstandard or beveled washers.

2. **Bolted Parts.** Assure bolted surfaces in contact with the bolt head and nut do not have a slope of more than 1:20 to a plane normal to the bolt axis.

   Assure bolted parts fit solidly when assembled without gaskets or other compressible material.

   Remove all mill scale, dirt, burrs, and other defects that prevent solid seating of the parts.

   Clean contact surfaces of oil, paint, lacquer, or galvanizing.

3. **Installation.** Install bolts with a hardened washer under the nut or bolt head, whichever element is turned in tightening. Use a hardened washer under the head of regular, semi-finished hexagon bolts and under finished hexagon nuts, even when these are not the elements turned in tightening. Washers may be omitted under the head of heavy hexagon bolts and interference-body bolts and under heavy, semifinished hexagon nuts, when these are not turned. A flat washer may be used when the surface adjacent to the bolt head or nut does not have a slope greater than 1:20 to a plane normal to the bolt axis. Use a smooth beveled washer where the outer face of the bolted parts has a slope greater than 1:20 to a plane normal to the bolt axis.

   Tighten each fastener to provide the minimum tension in Table 556-5 when all fasteners in the joint are tight.

   Tighten threaded bolts as specified in Subsections 556.03.9(E)(3)(a) or (b). Turn the bolt if the nut is prevented from rotating because of clearance problems.

TABLE 556-5

FASTENER TENSION

BOLT SIZE inch (mm)	MINIMUM FASTENER TENSION[1] pounds (A 325 BOLTS) (kN)
1/2 (13)	12,050 (53.5)
5/8 (16)	19,200 (85.3)
3/4 (19)	28,400 (126.2)
7/8 (22)	39,250 (174.4)
1 (25)	51,500 (228.9)
1 1/8 (29)	56,450 (250.9)
1 1/4 (32)	71,700 (318.7)
1 3/8 (35)	85,450 (379.8)
1 1/2 (38)	104,000 (462.2)
METRIC	
M16	94.2 kN
M20	147 kN
M22	182 kN
M24	212 kN

Notes:

1. Equal to 70 percent of specified minimum tensile strengths of bolts.

Impact wrenches perform the required tightening of each bolt in approximately ten seconds.

a. Turn-of-Nut Tightening. Bring a minimum 50 percent of the bolts up snug tight. Then bring the remaining bolts up snug tight. Then tighten all bolts starting with the inside bolts working towards the free edge under Table 556-6. Permit only the element being tightened to turn. Obtain the Project Manager's approval of the tightening method.

TABLE 556-6

NUT ROTATION FROM SNUG TIGHT CONDITION

Bolt Length, Measured From Underside of Head to Extreme End of Point	DISPOSITION OF OUTER FACES OF BOLTED PARTS		
	Both Faces Normal to Bolt Axis	One Face Normal to Bolt Axis and Other Face Sloped Not More Than 1:20 (Bevel Washers Not Used)	Both Faces Sloped Not More Than 1:20 From Normal to Bolt Axis (Bevel Washers Not Used)
Up to and including 4 diameters	1/3 turn	1/2 turn	2/3 turn
Over 4 diameters but not exceeding 8	1/2 turn	2/3 turn	5/6 turn
Over 8 diameters but not exceeding 12	2/3 turn	5/6 turn	1 turn

Nut rotation is relative to bolt regardless of the element (nut or bolt) being turned. For bolts tightened by one-half turn and less, the tolerance is plus or minus 30 degrees (1/12 turn); for bolts tightened by two-thirds turn or more, the tolerance is plus or minus 45 degrees (1/8 turn).

The rotation for bolts exceeding twelve diameters is by testing representative bolts in a tension device.

b. Calibrated Wrench Tightening. Provide bolt tension at least five percent more than the tension specified using calibrated wrenches. Calibrate wrenches at least once each working day for each bolt diameter installed. Re-calibrate wrenches when equipment changes or when differences in the surface condition of the bolts, nuts, or washers are observed. Calibrate by tightening three bolts of each diameter, in a Skidmore-Wilhelm calibrator or approved equal.

Adjust the wrenches to prevent nut or bolt rotation from exceeding that specified in Table 556-6. Tighten the nuts to the specified torque when using manual torque wrenches.

When using calibrated torque wrenches to install bolts in one joint, check the bolts with the wrench after initial tightening of all bolts.

Adjust power wrenches to stall or cut out at the required tension.

4. Inspection. The bolt installation will be inspected to verify procedures and results.

Bolt tension is checked in each connection by applying the job inspection torque to at least 10 percent of the bolts, but not less than two. If any element is below the job inspection torque, re-torque all bolts in the connection. Tighten and re-inspect any element turned by the job inspecting torque. As an alternate, the Contractor may re-tighten all bolts in the connection and request a re-inspection of the connection.

Assist the Inspector with bolt tension checks. Provide an approved torque wrench as the inspection wrench. The Inspector will observe the wrench readout as the bolt is being checked.

The job inspection torque is established from three bolts of the same grade, size, and condition as those in the work. The bolt length may be any length representing

bolt lengths used in the structure. A new inspecting torque is established when the bolt grade, size, or condition changes. Place the bolts in an approved calibration device that will indicate bolt tension. Use the same surface under the nut and bolt for testing as that used in the structure when establishing the inspection torque.

Bring the three bolts to an initial tension of approximately 15 percent of the fastener tension in Table 556-5, then tighten to the minimum tension in Table 556-5. Tightening above the initial tension must not cause nut rotation beyond that permitted in Table 556-6. Turn the turned element 5 degrees (approximately 1 inch (25 mm) at a 12-inch (300 mm) radius and read the applied torque. The average of the torque readings in the three tests is the job inspection torque.

556.03.10 Welding Requirements

Meet the current requirements of the American National Standard Bridge Welding Code, ANSI, AASHTO, the AWS Structural Welding Code, and the contract. Use AWS certified welders for the type of weld required.

556.03.11 Welded Stud Shear Connectors

The type, size or diameter, and length of stud shear connectors are specified in the contract.

Furnish fabrication material and perform welding meeting Subsection 556.03.10 requirements.

556.03.12 Field Welding

Do not weld temporary construction supports to beams, girders, or other main members. Unauthorized field welds, tack welds, or arc strikes to any member will be rejected.

556.03.13 Assembling Steel

Field or shop assemble steel parts as follows:

A. Shop Work. Clean all contacting metal surfaces of deleterious materials before assembling, bolting, or welding. Paint may be applied to contact surfaces after bolting or welding.

Shop assemble and adjust to line and camber all bolted trusses, continuous plate girders, curved steel elements, box girders, I-beam spans, skew portals, skew connections, rigid frames, bents, and towers.

Drill and ream the field splice holes during assembly. Holes for other field connections may be shop drilled or reamed with the connecting parts assembled or drilled or reamed to metal templates with hardened bushings, without assembling.

Use an approved alternate procedure where shop space prevents complete shop assembly of continuous span girders or trusses. The procedure may require adjusting the line and camber of at least two abutting sections of girder for drilling or reaming of field splices if all girder lines for the complete structure are assembled consecutively.

Field butt joints for welded girders may be assembled with abutting members adjusted for line and camber and prepared to fit for welding, subject to Project Manager approval.

Bridge expansion devices must be initially shop assembled to establish the proper fit between the joint parts.

B. Field Work. Assemble the parts as specified in the contract, following the match-marks. Prevent damaging the material while handling. Clean bearing surfaces and all member surfaces in permanent contact before assembly.

Splices and field connections must have a minimum of 1/2 of the holes filled with bolts or erection pins before removing temporary supports or releasing the load from

erecting equipment. Splices and connections carrying traffic during erection must have 3/4 of the holes pinned or bolted.

Do not begin production bolt tightening of the field splice bolts until the complete girder line is aligned and erected matching the full camber line.

Use erection pins 1/32-inch (1 mm) larger than the nominal diameter of the permanent bolts.

Erect truss spans on blocking, unless they are erected using the cantilever method, to provide truss camber. Leave the blocking in place until the tension cord splices are fully bolted and all other truss connections pinned and bolted. Do not tension bolts in butt joint splices of compression members and in railings until the span is swung.

C. **Drifting of Holes.** Only use drift pins during assembly to the extent necessary to bring the parts into position without enlarging or distorting the holes or metal. Enlarge holes by reaming to fit the bolts.

D. **Match-marking.** Match-mark parts assembled in the shop for reaming field connection holes and furnish the Project Manager a diagram showing the marks.

556.03.14 Marking and Shipping

Paint or mark each member with an erection mark, and furnish the Project Manager an erection diagram detailing the erection marks.

Furnish copies of material orders, shipping statements, and erection diagrams. Show the individual member weights on the statements.

A shipping statement must accompany the material and be marked to clearly identify it with the delivered material and mill test reports.

Mark the weight on members weighing 3 tons (2.7 t) or more. Load and unload structural members on trucks or cars without stressing or causing damage.

Pack bolts, loose nuts or washers of each size separately. Ship pins, small parts, bolts, washers, and nuts in boxes, crates, kegs, or barrels, with the gross weight of each package not exceeding 300 pounds (136 kg). Plainly mark each shipping container, listing and describing the contents on the outside of each shipping container.

Keep structural material clean and free from damage.

556.03.15 Painting

Clean and paint all iron and steel surfaces meeting Section 612 requirements.

556.03.16 Erection

Erect the members using the camber diagrams on the drawings and complete the structure or structures as specified.

When requested, furnish the Project Manager erection details before starting the work.

Support girders and beams at intervals that maintain camber, elevation, and horizontal alignment during final grading, bolt-up, and field splice tightening.

556.03.17 Handling and Storing Materials

Store materials off the ground and keep them clean and dry. Place and shore girders and beams upright. Support long members, including but not limited to columns, chords, and girders, on blocks spaced to prevent deflection. For erection contracts, check the material received against the shipping lists and report in writing all shortages and damaged materials. Be responsible for lost or damaged material while in Contractor possession.

556.03.18 Falsework

Design, construct, and maintain falsework to support the maximum construction loadings. Check and approve falsework drawings before submitting. The Department has 20 working days

to review and return the falsework drawings. The contract time will be extended day for day for any delay beyond the 20-day review period if the Department's delay affects the Contractor's operation as shown on the current work schedule.

556.03.19 Bearing and Anchorage

Place masonry bearing plates on bearing areas that meet specifications. Install bearing plates level to provide an even bearing on the masonry.

Place masonry bearing plates on fiber-reinforced pads meeting Subsection 711.16, that project at least 1/2 inch (13mm) on all sides of the bearing plate.

Make allowances for bottom chord elongation due to dead load when setting shoes or bearing plates for steel truss spans.

Install bridge rocker shoes to be vertical under full dead load at 60 °F (15 °C). Raise spans and make adjustments if the rockers are not correctly positioned with the final dead load on spans.

Construct concrete surfaces receiving elastomeric pads to compensate for bearing pad compression. Finish the bearing area with a wood float to a level plane. The surface must not vary by more than 1/16 inch (2 mm) from a straightedge placed in any direction across the area. Extend the bearing area at least 1 inch (25 mm) beyond the elastomeric bearing pad dimensions. The finished elevation of the bearing surface must not vary by more than 1/8 inch (3 mm) from the specified beam-seat elevation unless otherwise approved.

556.03.20 Placing Anchor Bolts

Place anchor bolts meeting Subsection 552.03.14 requirements.

556.03.21 Straightening Bent Material

Straighten bent plates, angles or other shapes without damaging the material. The metal may be heated if approved. Do not exceed 1,000 °F (537 °C). Once heated, cool the metal slowly.

All straightened metal will be inspected for defects.

556.03.22 Pin Connections

Furnish the Project Manager the pilot and driving nuts provided with the steelwork once the work is complete. The members must take full bearing on the pins. Bring pin nuts up tight, and burr the threads at the nut face.

556.03.23 Misfits

Correct all misfits, errors, and injuries as a part of the assembly and erection work. Report to the Project Manager all shop work errors that prevent the assembly and fitting of parts with a minimum use of drift pins, reaming, slight chipping or cutting. Obtain Department approval for the correction method. Corrections must be inspected and approved.

556.03.24 Cleanup

Remove all falsework, excavated or unused materials, rubbish, and temporary buildings. Restore all public and private property damaged during construction to its original condition.

Pull, cut off or otherwise remove all falsework piling 1 foot (305 mm) below finished the ground line or streambed, unless otherwise directed. Perform all work affecting the stream channel meeting the applicable requirements of Subsection 208.03.4 before final acceptance.

556.03.25 Rejections

An Inspector's acceptance of material or finished members does not prevent later rejection if defects are found. Replace or repair rejected material and work at Contractor expense.

556.04 METHOD OF MEASUREMENT

Structural steel is measured by the lump sum.

556.05 BASIS OF PAYMENT

Payment for the completed and accepted quantities is made under the following:

Pay Item	Pay Unit
Structural Steel	Lump Sum

The weight of structural steel in the contract is an estimate only. No guarantee is made that the estimated weight is the correct weight to be furnished. No adjustment in the contract unit price is made if the weight furnished is more or less than the estimated weight.

If changes in the work ordered by the Project Manager vary the weight of steel to be furnished, the lump sum payment is adjusted as follows:

The value per pound (kilogram) of a decrease or increase in the weight of structural steel involved is determined by the following:

$$\text{Value Per Pound (kilogram)} = \frac{\text{Contract Lump Sum Bid}}{\text{Estimated Contract Weight}}$$

The adjusted contract lump sum amount paid is the contract lump sum bid plus or minus the value of steel involved in the change.

Should the ordered change materially alter the character of the work and the unit cost, compensation for that work is made at an agreed price established before the work is performed. Detail, in writing, the changes in procedures and the resulting costs for labor, equipment, and materials to support the agreed price.

Partial payments for structural steel will be made based on the lump sum contract unit price as follows:

1. 90 percent when erected.
2. 97 percent when bolted and spot painted.
3. 100 percent when painted in compliance with the plans and specifications.

Payment at the contract unit price is full compensation for all resources necessary to complete the item of work under the contract.

SECTION 557
STEEL BRIDGE RAILING

557.01 DESCRIPTION

This work is the furnishing and installing of steel bridge railing.

557.02 MATERIALS

Furnish materials meeting the following Subsection requirements:

Structural Steel Tubing 711.03
High Tensile Strength Anchor Bolts.....711.06
Galvanized Metal 711.08
Structural Steel 711.02
Steel Beam Guardrail and Wood Blocks.....705.01
Fiber-reinforced Pads for Rail Post Base Plates.....711.16

557.03 CONSTRUCTION REQUIREMENTS

557.03.1 Fabrication Drawings

Furnish fabrication drawings for steel bridge railing meeting Subsection 556.03.2 requirements.

557.03.2 Fabrication

Fabricate steel bridge railing meeting the applicable requirements of Section 556.

557.03.3 Erection

Construct steel bridge railing as shown on the plans. Adjust the completed railing to compensate for any unevenness in the structure. Assure all rail posts are vertical. Do not place railing on a span until centering or falsework is removed. Place rail post base plates on fiber-reinforced pads, sized and positioned to project a minimum 1/2 inch (13 mm) on all sides of the base plates.

557.03.4 Painting

Clean and paint steel bridge railing specified to be painted meeting Section 612 requirements.

557.04 METHOD OF MEASUREMENT

Steel bridge railing of the type or types specified is measured by the foot (meter). Measurement is based on the computed horizontal distance between the centerlines of end base plates.

557.05 BASIS OF PAYMENT

Payment for the completed and accepted quantities is made under the following:

Pay Item	Pay Unit
Bridge Railing	Foot (meter)

Partial payments of steel bridge railing will be made based on the total quantity as follows:

1. 90 percent when erected.
2. 95 percent when bolted and spot painted.
3. 100 percent when painted in compliance with the contract.

Payment at the contract unit price is full compensation for all resources necessary to complete the item of work under the contract.

SECTION 558
TIMBER STRUCTURES

558.01 DESCRIPTION

This work is furnishing materials for, and constructing timber structures and the timber portions of composite structures.

558.02 MATERIALS

Furnish materials meeting the following Subsection requirements:

Treated and Untreated Timber Piles	706.05
Structural Timber and Lumber	706.01
Treated Timber	706.04
Bolts and Nuts	711.07
Galvanized Metal	711.08
Structural Steel	711.02
Crushed Top Surfacing	701.02

Drift-pins and dowels may be wrought iron or medium steel.

Furnish washers made of iron castings or malleable castings, unless otherwise specified.

Furnish galvanized or cadmium plated hardware, except cast iron washers, meeting ASTM A 165, Type OS.

558.03 CONSTRUCTION REQUIREMENTS

558.03.1 Construction Drawings

Furnish shop drawings that detail the material grade, cutting, framing, boring details, dimensions, size of material, and all other information necessary for fabrication and erection of the timber.

Furnish all shop drawings on 22-inch x 36-inch paper (A1 paper) with a 1 1/2-inch (46 mm) margin on the left side and a 1/2-inch (43 mm) margin on the other three sides.

Check and approve fabrication drawings before submitting. The Contractor approval must be shown on the drawings. Do not begin cutting and framing until the drawings are returned by the Project Manager.

558.03.2 Handling of Materials

Handle timber without dropping, breaking outer fibers, bruising, or penetrating the timber surface. Use rope slings to handle treated timber.

558.03.3 Storage of Materials

Store timber in neat stacks on ground free of weeds and rubbish.

Open-stack untreated timber at least 12 inches (300 mm) above the ground. Cover timbers as required to protect them from weather. Close-stack treated timbers to prevent warping.

558.03.4 Treatment of Breaks and New Cuts

Trim and treat all cuts and abrasions in treated timbers with three applications of a solution of copper naphthenate containing a minimum of two percent copper metal or with chromated copper arsenate (CCA) meeting AWPA M4. Follow treatment with one coat of hot tar.

558.03.5 Temporary Attachment

Attach forms or temporary braces to treated timber with nails or spikes. Once the nails or spikes are removed, fill the holes by driving galvanized nails or spikes flush with the surface or plugging with creosote plugs after treating the holes with creosote oil.

558.03.6 Bearing

Level post and pile caps to provide full, even bearing on all posts or piles in the bent. Secure caps to each pile or post using a 3/4-inch (19 mm) diameter drift-pin extending at least 9 inches (230 mm) into the pile or post center.

558.03.7 Sills and Mud Sills

Evenly bed mud sills to solid bearing and tamp in place. Assure sills have true and even bearing on concrete sills, piles, or pedestals. Drift-bolt sills to mud sills or piles with 3/4-inch (19 mm) diameter bolts or larger extending into the concrete sills or piles at least 6 inches (155 mm). Remove all soil in contact with sills to provide free air circulation.

558.03.8 Framing

Cut timber for framing before treating with preservatives.

Cut and frame truss and bent timbers to a close fit providing even bearing over the entire joint contact surface. Blocking, shimming or open joints are not allowed.

Construct mortises true to size for the full depth. Fit tenons snugly in mortises.

Accurately frame cross bridging between stringers at the center of span and securely toe-nail with at least 2 nails in each end. Assure all cross-bridging members have full bearing at each end against the sides of stringers.

558.03.9 Bolt Holes

Size holes for drift-pins, dowels, and bolts the same diameter of the pin or dowel to be used. Do not make holes for lag screws larger than the body of the screw at the base of the thread. Make holes for rods 1/16 inch (2 mm) larger in diameter than the rod.

Treat all bore holes in treated timber, made after treatment, with an approved pressure bolt hole treater. Seal holes for rods with hot tar or other approved waterproofing once the rods are inserted.

Countersink where smooth faces are specified. Treat horizontal recesses formed for countersinking with 3 applications of copper naphthenate containing a minimum of two percent copper metal or with chromated copper arsenate (CCA) meeting AWPA M4. Fill the countersink with hot tar once the bolt or screw is in place.

558.03.10 Stringer Sizing

Size stringers between bearing points only. Make butt joints for outside stringers. Frame interior stringers to bear over the full width of floor beam or cap at each end. Securely anchor the stringer ends to the cap. Separate untreated timbers at least 1/2 inch (13 mm) for air circulation.

558.03.11 Roadway Floors

Make roadway floors strip or laminated as specified, surfaced S1S1E or S4S.

A. Laminated Floors. Place the strips on edge and draw down tightly against the stringer or nailing strip and the adjacent strip and spike them. Extend each strip the full deck width unless otherwise specified.

Spike each strip to the adjacent strip at intervals not exceeding 2 feet (610 mm), staggering the spikes 8 inches (205 mm) in adjacent strips. Use spikes long enough to pass through 2 1/2 strips. Toe-nail each strip to alternate stringers with 40d (125 mm x 5.7 mm) common nails with adjacent strips nailed to every alternate stringer unless

bolting is specified. Toe-nail the ends of all strips to the outside stringer. Cut off the strip ends on a true line parallel to the centerline of the roadway. When bolts are used to fasten laminated floors to stringers, space the bolts as specified and draw them down tightly on the bolting strips. Draw the bolt heads down flush with the deck surface. Use double nuts or single nuts with lock washers on all bolts. Spike the strips as specified above.

B. Plank Floors. Make plank floors out of a single thickness of plank on stringers or joists. Unless otherwise specified, lay the planks heart side down. Spike planks to each joist or nailing strip with at least two spikes that are 4 inches (100 mm) longer than the plank thickness. Spike the planks at least 2 1/2 inches (64 mm) from the edges with the edges cut off on a straight line parallel to the roadway centerline. Adjacent planks must not vary in thickness by more than 1/16-inch (2 mm). Planks are S1S1E unless otherwise specified.

558.03.12 Deck Surface Treatment

Treat the entire top surface of the deck and the inside surfaces of curbs with hot tar meeting ASTM D 490, Grade RT-7 or RT-8 (RT-7 is adapted to cold-weather application, RT-8 to warm-weather application).

Heat the tar in an open tank or kettle to between 200 °F to 225 °F (93 °C to 107 °C). Apply three even coats to the surfaces to be treated, each at 1/4 gallon per square yard (1.1 L per square meter). Allow each coat sufficient time to cool and set up before applying the next coat.

After the final coat of tar has cooled and set up, cover the entire deck surface with aggregate surfacing at 1 cubic yard per 24 square yards (1 cubic meter per 25 square meters) of surface area before opening to traffic. Furnish aggregate surfacing meeting the requirements of crushed top surfacing Type A Grade 2 or 3, or Type B Grade 3, except that the material passing the 200-mesh (0.075 mm) sieve may not exceed 10 percent.

558.03.13 Wheel Guards

Bolt wheel guards to the outside stringers using 3/4-inch (19 mm) machine or hook bolts spaced a maximum 5 feet (1525 mm) center-to-center. Lap all joints. A bolts must pass through each lapped joint.

Provide drain holes as specified. Line the drain holes with galvanized iron lining, positioned to discharge free of the structure.

558.03.14 Reserved

558.03.15 Nailing

Drill holes for nails that are driven near timber ends. Drill the hole only in the piece to be attached. Drill the hole smaller than the nail to provide a tight fit.

558.03.16 Washers

Use washers behind all bolt heads and nuts. Place washers for carriage bolts and large-head timber bolts under the nuts only.

Use cast-washers of the thickness equal to the bolt diameter and a diameter four times the thickness. Use malleable and plate washers with a thickness equal to one-half the diameter of the bolt, and the length of each side equal to four times the bolt diameter.

Use cast iron washers when timber is in contact with earth.

558.03.17 Treating and Painting Untreated Timbers

Treat the following surfaces with three applications of copper naphthenate containing a minimum of two percent copper metal or with Chromated Copper Arsenate (CCA) meeting AWPA M4 requirements:

1. Ends, tops, and all post contact surfaces, sills, caps, floor beams, and stringers;
2. Ends, joints, and contact surfaces of bracing and truss members;
3. Timber bumper surfaces;
4. The back face of bulkheads; and
5. All other untreated timber that is in contact with earth.

558.04 METHOD OF MEASUREMENT

Treated and untreated timber and lumber is measured by the thousand feet board measure (cubic meter) based on nominal actual thicknesses and widths. Measurements are computed using the plan dimensions unless changes in plan dimensions are approved by the Engineer. The actual lengths (volume) of the individual pieces in the finished structure will be measured, without deductions for daps, cuts, or splices.

The measurement of laminated timber decking is based on the number of pieces of the size or sizes specified, after dressing, and the actual lengths used in the structure.

Measurements consist of only timber that is a part of the completed and accepted work and does not include timber used for erection, such as falsework, forms, bracing, and sheeting.

558.05 BASIS OF PAYMENT

Payment for the completed and accepted work is made under the following:

Pay Item	Pay Unit
Treated and Un-treated Timber	Thousand Board Foot (cubic meter)

Payment at the contract unit price is full compensation for all resources necessary to complete the item of work under the contract.

SECTION 559
PILING

559.01 DESCRIPTION

This work consists of furnishing and placing piling.

559.02 MATERIALS

Furnish materials meeting the following Section and Subsection requirements:

Portland Cement Concrete 501
Structural Steel Piles 711.10.1
Steel Pipe Piles.....711.10.2

559.02.1 Inspection of Steel Pile

Steel pile may be inspected at the rolling mill and will be inspected at the project.

Furnish copies of the mill test reports showing the chemical and physical test results for each steel pile heat number included in the shipment.

Provide steel pile with a maximum camber or sweep of 0.013 inches per foot (1 mm per meter) of pile length.

Store and handle steel piles to prevent damage. Bent, deformed, or kinked piles will be rejected.

559.02.2 Furnish Pile

Furnish pile quantities shown in the contract.

The specified lengths are those required below cutoff. Adjust lengths for the difference between the cut off length and the pile position in the driving equipment. Increase pile lengths 1 foot (300 mm) for steel pile. Remove and dispose of excess pile length after the pile is driven.

559.02.3 Metal Pile End Protection

Furnish prefabricated cast steel driving point or cutting shoe conforming to ASTM A27 requirements. Furnish cast steel driving point for H-pile. Furnish cast steel inside-flanged, open-end cutting shoe or 60-degree, inside-flanged conical driving point for pipe pile as specified. Weld driving point or cutting shoe to steel pile in accordance with ANSI/AASHTO/AWS D1.1 or D1.5, as applicable. Use welders certified by the Department or a Certified Welding Inspector.

559.02.04 Splicing Piles

Splice piles driven to plan grade that do not obtain the required driving resistance and continue driving until the required capacity is obtained. Weld steel pile in accordance with AWS D1.5 requirements. Use 10-foot (3-meter) minimum spacing for steel pile splice welds. When steel piles are driven less than 10 feet (3 meters) below the cutoff elevation specified, use one splice to obtain the required cutoff elevation.

559.03 CONSTRUCTION REQUIREMENTS

559.03.1 Equipment for Driving Pile

A. Pile Hammers. Drive piles with impact hammers that include air, steam, diesel or hydraulic hammers.

For air or steam hammers, provide equipment that maintains the volume as specified by the manufacturer of the hammer as the pile is driven. Provide equipment with accurate pressure gauges that are easily read from ground level. Ensure that the striking parts of

the hammer are at least 1/3 the weight of the helmet and the pile being driven or 2,750 lbs. (1,250 kg), whichever is greater.

Provide open-end (single-acting) diesel hammers with rings or other indicators on the ram that permit visual determination of the hammer stroke as the pile is driven. Submit a copy of the hammer manufacturer's chart that equates the stroke and blows per minute for the hammer being used.

Provide closed-end (double-acting) hammers with an accurate bounce chamber pressure gauge that is easily read from ground level. Submit a copy of a chart, calibrated to the actual hammer performance that equates the bounce chamber pressure to the equivalent energy or stroke of the hammer.

Provide equipment for hydraulic hammers that are sized to maintain the manufacturer's specified volume and pressure during driving. Provide equipment with accurate pressure gauges that are easily read from ground level.

Delays and additional costs resulting from load tests or other extra work required to verify approval of the vibratory hammer or driving aids is at Contractor's expense. If a vibratory hammer is used, re-drive each pile with an impact hammer having the energy to verify the ultimate pile capacity, as required in Subsection 559.03.3.

B. Pile Driving Aides and Accessories.

1. **Followers.** Do not use followers.
2. **Helmet.** Provide metal helmets for pile to be driven by impact drivers. Helmets must fit around the pile top, align axially with the hammer and pile, distribute the hammer energy to the total pile head cross section and have leads to guide them.
3. **Hammer Cushion.** When driving pile with an impact hammer, use a cushion to prevent damage to the pile and hammer. Use a cushion recommended and approved by the hammer manufacturer. Use a striker plate recommended by the hammer manufacturer on the hammer cushion to provide uniform compression of the cushion material.
4. **Leads.** Support the piles in line and position during driving. Use pile hammer leads that permit free movement of the hammer, maintain hammer and pile alignment and provide concentric impact for each blow.
5. **Jets.** Do not use water jets.
6. **Caps.** Follow the pile manufacturer's recommendations regarding caps, driving heads, mandrels or other required devices.

C. Pile Pre-drilling. When specified in the plans, use the prescribed drilling methods discussed in this specification. Do not impair the capacity of previously installed pile or the safety of adjacent structures. If drilling reduces the capacity of previously placed pile, restore the disturbed pile to conditions meeting this specification by re-driving after drilling operations in the area have been completed.

1. **Pile Pre-bore.** When pile pre-bore is specified, use an auger, wet-rotary drill or other approved method. Drill pre-bore holes to the specified diameter and depth. Drive the pile in the pre-bore hole, starting from the bottom of the hole, with an impact hammer evaluated in accordance with Subsection 559.03.2. Continue driving the pile to the ultimate pile capacity and the depth specified. After driving, fill the annular void around the pile with dry, fine concrete aggregate meeting the requirements of Subsection 701.01.1 and Table 701-2.
2. **Pile Drill and Socket.** At each pile location, drill pilot holes a maximum of one inch (25 mm) in diameter less than the outside diameter of the round pile and a maximum of 4 inches (100 mm) less than the outside diagonal cross sectional measurement of square or H-pile, to the elevation specified. Drive the pile into the pre-drilled pilot hole

to the bottom of the hole with an impact hammer evaluated in accordance with Subsection 559.03.2. Continue driving the pile below the bottom of the drilled hole to the design tip elevation specified in the plans, or deeper if directed by the Project Manager.

559.03.2 Evaluation of Pile Driving Equipment

The Department will evaluate pile-driving equipment provided by the Contractor. The equipment must have the capability to drive the project pile to the design pile tip elevation and required ultimate pile capacity without damage to the pile. When dynamic load tests are required by the contract, submit a wave equation analysis performed by a pile specialty consultant meeting the requirements of Subsection 559.03.3(B)(2). The Department will base hammer evaluations on wave equation analysis. Submit the pile driving equipment information on Form CSB559_03_2. Provide pile-driving equipment that produces the following results from the wave equation analysis:

- 35 to 120 blows per one foot (0.3 meter) at ultimate capacity; and
- Maximum compressive driving stress less than 90 percent of the minimum pile material yield strength.

The Project Manager will notify the Contractor of results of the pile driving equipment evaluation within 14 calendar days after receipt of the Pile and Driving Equipment Data form. If the wave equation analysis indicates that pile damage may occur or that the proposed pile driving equipment cannot drive the pile to the specified ultimate capacity, re-submit a plan that modifies the equipment or the method to ensure the ability to drive pile to the specified ultimate capacity without pile damage. The Project Manager will notify the Contractor of results of the revised pile driving submission within seven calendar days after receipt of the re-submittal.

Do not vary from the evaluated driving system without prior written approval. The Department will consider proposed changes to the pile driving equipment or method only after submittal of revised information for a new wave equation analysis. The Project Manager will notify the Contractor of evaluation results of the pile driving system changes within seven calendar days after receipt of the submittal. Delays and additional costs associated with developing, submitting and obtaining evaluation results for pile driving proposals and resulting changes in the pile driving equipment and work methods are at Contractor’s expense.

559.03.3 Pile Capacity

A. Driven Pile Capacity. Drive the pile to the design tip elevation shown on the plans or deeper, if necessary, to reach ultimate pile capacity. The Project Manager will use one of the following methods specified to determine ultimate driven pile capacity.

1. **Wave Equation.** The Department will determine ultimate pile capacity based on a wave equation analysis. Drive piles with the pile driving equipment evaluated in accordance with Subsection 559.03.2 to the depths necessary to obtain ultimate pile capacity. Do not use other methods to aid pile penetration, unless specified or approved after a revised driving resistance is established from the wave equation analysis. Unless otherwise specified, adequate pile penetration consists of reaching the specified wave equation resistance criteria within 1 foot (0.3 meter) of the pile tip elevation. Drive pile not achieving the specified resistance within these limits to penetrations established by the Project Manager.
2. **Dynamic Formula.** The Department will determine ultimate pile capacity based on a dynamic formula. Drive pile to obtain the ultimate pile capacity determined by the following formula:

$$R_u = 1.75 \sqrt{E} \log_{10}(10N_b) - 100 \quad \text{(English)}$$

Where:

R_u = Ultimate pile capacity in kips

E = Manufacturer's rated hammer energy in foot-pounds at the Field observed ram stroke

$\log_{10}(10N_b)$ = Logarithm, to the base 10, of the quantity, 10 multiplied by N_b, the number of hammer blows per inch at final penetration

$$R_u = [7 (E_r^{1/2}) \log_{10}(10N_b)] - 550 \quad \text{(metric)}$$

Where:

R_u = Ultimate pile capacity in kN

E_r = Manufacturer's rated hammer energy in Joules at the field observed ram stroke

$\log_{10}(10N_b)$ = Logarithm, to the base 10, of the quantity, 10 multiplied by N_b, the number of hammer blows per 25 mm at final penetration

B. Compression Load Tests.

1. Static Load Tests. If specified, perform compression load tests to meet the requirements of ASTM D-1143 using the Quick Load test method. Load the test pile to the required ultimate capacity shown on the plans. Provide testing equipment and measuring systems meeting ASTM D-1143, except the loading system must be capable of applying 150 percent (150 percent) of the ultimate pile capacity. Provide a load cell and spherical bearing plate. Submit detailed plans for the proposed loading system prepared by a professional engineer licensed in the State of Montana for approval. The load system must gradually and incrementally place the load on the test pile without vibration. If the static load test method includes tension (reaction) anchor pile, provide anchor pile of the same type and size as the service pile. Drive the anchor pile in a permanent pile location, unless the Project Manager approves another location.

Determine top elevation of the test and anchor pile immediately after driving and again just before load testing to check for heave. Re-drive all pile that heaved in excess of 1/4 inch (6 mm) or jack the pile to the original elevation before testing. Wait 72 hours between driving the anchor pile or the load test pile and performing the load test.

Define the failure load for a tested pile as the axial compressive load that produces a settlement of the pile head equal to:

a. For piles 2 feet (610 mm) or less in diameter or width:

$$s_f = \Delta + (0.15 + 0.008b) \quad \text{(English)}$$

$$s_f = \Delta + (4.0 + 0.008b) \quad \text{(metric)}$$

b. For piles greater than 2 feet (610 mm) in diameter or width:

$$s_f = \Delta + b / 30 \quad \text{(English and metric)}$$

Where:

s_f = Settlement at failure in inches (millimeters)

b = Pile diameter or diagonal width in inches (millimeters)

Δ = Elastic deformation of total pile length in inches (millimeters)

If the Project Manager determines that the pile has failed before achieving the ultimate capacity, perform additional load tests. The Department will measure and pay for each additional load test.

When load testing is complete, remove all test or anchor pile not part of the finished structure or cut them off at least 1 foot (300 mm) below the bottom of the footing or below the finished ground elevation, if the pile fall outside the footing area.

2. **Dynamic Load Tests.** Use a pile specialty consultant with at least three years experience in dynamic load testing and analysis to perform the dynamic load test, Case Pile Wave Analysis Program (CAPWAP) and the wave equation analysis, including the initial wave equation analysis specified in Subsection 559.03.2. Use a Geotechnical Engineer licensed as a Professional Engineer in Montana who has achieved at least Advanced Level on the Foundation QA Examination for Providers of PDA Testing Services to perform the CAPWAP analysis. Use a technician with a Basic Level classification on the Foundation QA Examination for Providers of PDA Testing Services Operation to operate the Pile Driving Analyzer. Provide the specialty consultant on site during the dynamic load tests. Submit the specialty consultant's resume for approval.

   Furnish digital data acquisition system equipment with a display screen and printer. Perform dynamic load tests in accordance with ASTM D 4945 on the pile designated for dynamic load tests.

   With dynamic testing equipment attached, drive the pile to the design tip elevation, or deeper if directed by the Project Manager. The Project Manager will use the ultimate pile capacity measurements at the time of driving or re-driving to determine the required pile tip elevation. Reduce the driving energy to the pile to maintain pile stresses below the values specified in Subsection 559.03.3(A)(2), using additional cushions or reduction of the hammer's output energy. If eccentric driving is indicated, immediately re-align the driving system. Provide a printed summary of the dynamic load test results and recommendations for production pile driving criteria (blow count and stroke) and pile tip elevation. The Project Manager will determine the production pile driving criteria and minimum pile tip elevations based on the dynamic load test results and specialty consultant's recommendations.

   If the Project Manager requires a re-drive, each re-drive will be measured and paid for as an additional dynamic load test by the Department. After initial driving, wait the minimum time specified, then re-drive each dynamic load test pile with the instruments attached. Apply at least 20 resistance blows to warm the hammer before re-driving. Do not warm the hammer using the dynamic load test pile. Re-drive the dynamic load test pile for a maximum penetration of 6 inches (150 mm), a maximum of 50 blows or to practical refusal, whichever occurs first. Practical refusal is considered as 15 blows per inch (25 mm) for steel piles.

   Verify the assumption used in the initial wave equation analysis submitted in Subsection 559.03.3(A)(1) using CAPWAP. Analyze one blow from the original driving and one blow from the re-driving for each pile tested.

   Perform additional wave equation analysis with adjustments based on the CAPWAP results. Provide a graph showing blow count versus ultimate capacity. For open-ended diesel hammers, provide a blow count versus stroke graph for the ultimate capacity. Provide the driving stresses, transferred energy and pile capacity as a function of depth for each dynamic load test. Submit a written report with numerical and graphical results of the dynamic load testing, CAPWAP analysis and wave equation analysis.

C. Vibratory Hammer. Base the ultimate pile capacity of pile driven with vibratory hammers on the driving resistance recorded during impact driving after the vibratory equipment has been removed. Splice vibrated pile not reaching the ultimate pile capacity at the design tip elevation at the Contractor's expense, then drive with an impact hammer until the ultimate pile capacity is achieved as indicated by the requirements of Subsection 559.03.3.

559.03.4 Pile Driving Location and Alignment

Drive piles so the pile head at cutoff elevation is horizontally within 2 inches (50 mm) of the plan location for bent caps supported by piles and within 6 inches (150 mm) of plan location for piles capped below final grade. Ensure no pile is within 4 inches (100 mm) of a cap edge.

The allowable alignment tolerance from a plumb line is 3/4 inch per yard (20 mm per 1,000 mm) of pile length.

The Project Manager may suspend driving if the either the pile location or alignment is not maintained as the pile is driven.

Submit a written plan for correcting piles that do not meet the alignment or location tolerances.

Laterally pulling on mis-aligned pile or splicing a properly aligned section on mis-aligned piles is not allowed.

559.03.5 Service Pile

Drive service pile to the specified pile tip elevation and ultimate pile capacity. If specified, establish pile tip elevation and ultimate pile capacity by compression load testing or dynamic load testing.

Furnish the service pile lengths specified in the contract. Adjust pile lengths for the difference between cutoff length and the pile position in the driving equipment.

Drive each service pile in one continuous operation unless the Department requires a re-drive.

The Project Manager will observe the pile driving and calculate the predicted pile capacity as it is being driven.

Stop pile driving if the pile top is within 2 feet (610 mm) of cutoff elevation and the predicted capacity has exceeded the required capacity.

Re-drive the pile not less than 24 hours or more than 72 hours after initial driving and do not drive the pile below cut off elevation. If the Project Manager determines pile stresses during driving are damaging the pile, the Department may require other installation methods or equipment to obtain pile penetration.

Correct or replace improperly driven, damaged or defective pile at Contractor's expense.

559.03.6 Cutting Off Steel Pile or Steel Pipe Pile

Cut steel pile heads square and furnish a driving cap before driving the pile. After driving piles to the required capacity, cut piles off at the specified elevation.

559.03.7 Steel Pipe Pile

Remove water in steel pipe piles before placing concrete or place the concrete using a tremie when water is present in the pile.

Provide lighting to illuminate the full pile length when requested to aid inspection of the pile before placing concrete. Fill steel pipe piles to the cut off elevation with Class "DD" portland cement concrete.

Do not place concrete in pipe piles until all piles for the bent have been driven.

559.03.8 Painting Steel Pile or Steel Pipe Pile

Paint steel pile having a portion of the pile exposed to the atmosphere meeting the following requirements.

A. Paint. Furnish paint meeting the requirements of Subsection 710.02(B)(4).

B. Surface Preparation. Prepare the pile surface to the paint manufacturer's recommendations.

C. Painting. Before driving, apply two coats of paint to the pile starting a minimum of 2 feet (610 mm) below finish ground surface or finish channel bottom to the top of exposed steel.

Apply the first two paint coats to produce a minimum 12 mils (300 μm) dry film thickness. Field repair paint damage caused by transport, splicing and handling following the paint manufacturer's recommendations before applying the finish coat.

When piles are in the final location in the structure, apply the finish coat paint. Provide a finish coat with a minimum 3 mils (75 μm) dry film thickness on all surfaces exposed to the air at time of paint application. The Project Manager will select the finish coat paint color from one of the following:

TABLE 559-1

FINISH COAT PAINT COLOR

COLOR	FEDERAL SPECIFICATION 595B PIGMENT CODE
Montana Brown	33578
Montana Blue	35450
Montana Green	34138
Concrete Gray	36440

559.04 METHOD OF MEASUREMENT

559.04.1 Load Tests

Static and dynamic load tests completed and accepted are measured by the unit. Include all materials, tools and equipment required to perform each test. Furnishing, driving, splices, and pile end protection are measured for payment as outlined in other Subsections. Do not include these costs in the static and dynamic load tests.

559.04.2 Furnish Pile

Furnish pile is measured by the foot (meter) based on the plan quantity or the length between the pile tip and the cutoff elevation. Pile furnished in addition to the plan quantity is measured for payment.

559.04.3 Drive Pile

Drive pile is measured by the foot (meter) of pile driven into the ground. Drive pile is measured by the foot (meter) of pile driven through pile drill and socket pilot holes. Pile driven through pre-bore holes is not measured for payment.

559.04.4 Pile Pre-drilling

Pile pre-bore and pile drill and socket pilot holes are measured by the foot (meter) drilled below the existing or finished ground elevation to the bottom of the hole.

559.04.5 Pile Splice

When the pile tip extends more than 1 foot (300 mm) below the plan estimated pile tip elevation, splices required to obtain specified cutoff elevation are measured for payment. Pile splices are measured by the number of pile splices performed in the field and approved by the Project Manager.

Splices made for Contractor convenience, to facilitate driving operations, or to produce pile sections meeting specified design lengths are not measured for payment.

559.04.6 Pile Driving Point and Cutting Shoe

Pile driving point and cutting shoe are measured by the unit for the quantity specified in the contract.

559.04.7 Filler Concrete

Filler concrete is not measured for payment.

559.04.8 Painting Steel Pile and Steel Pipe Pile

Painting steel pile and steel pipe pile is not measured for payment.

559.05 BASIS OF PAYMENT

The Department will not pay for furnishing or driving falsework pile, pile driven out of place, defective pile, or pile damaged in handling or driving.

Include payment for the costs associated with painting steel pile and steel pipe piles and filler concrete in the contract unit price per foot (meter) of drive pile.

Pile furnished, based on the plan quantities, but not incorporated in the finished structure, is paid for at the contract unit price per foot (meter) of furnish pile and becomes the property of the Contractor. Pile furnished in addition to plan quantity that is incorporated in the finished structure, is paid for at invoice price.

Payment for the completed and accepted quantities is made under the following:

Pay Item	Pay Unit
Static Load Test	Each
Dynamic Load Test	Each
Furnish Pile	Foot (meter)
Drive Pile	Foot (meter)
Pile Pre-bore	Foot (meter)
Pile Drill and Socket	Foot (meter)
Pile Splice	Force Account
Pile Driving Point	Each
Pile Conical Driving Point	Each
Pile Cutting Shoe	Each

Partial payments for drive pile will be made based on the total quantity as follows:

1. 95 percent when the piles are driven to final penetration.
2. 100 percent when the piles are cut off and painted as specified.

Payment at the contract unit price is full compensation for all resources necessary to complete the item of work under the contract.